Module 1: Solar Power
6th Grade

About the Instructions:

This document is intended for use by classroom teachers, SciTrek leads, and SciTrek volunteers. The document has been composed with input from teachers, leads, volunteers, and SciTrek staff to provide suggestions to future teachers/leads/volunteers. The instructions are not intended to be used as a direct script, but were written to provide teachers/leads/volunteers with a guideline to present the information that has worked in the past. Teachers/leads/volunteers should feel free to deviate from the instructions to help students reach the learning objectives of the module. Places in which you can be creative and mold the program to meet your individual teaching style, or to meet the needs of students in the class are: during class discussions, managing the groups/class, generating alternative examples, and asking students leading questions. However, while running the module make sure to cover all the material each day within the scheduled 60 minutes. In addition, no changes should be made to the academic language surrounding the Analysis Activity.

This 6th grade module has been designed to build upon the scientific practice taught in 5th grade SciTrek, conclusions. As a result, the 6th grade SciTrek program is only available to classes that completed 5th grade SciTrek in the previous year.

Activity Schedule:
There are no scheduling restrictions for this module.

Day 1: Analysis Assessment/Observations/Technique/Variables (60 minutes)
Day 2: Question/Materials Page/Experimental Set-Up/Procedure/Results Table (60 minutes)
Day 3: Experiment/Analysis Activity/Conclusion (60 minutes)
Day 4: Technique 1/Technique 2/Analysis Activity (60 minutes)
Day 5: Discussion/Question/Materials Page/Experimental Set-Up/Procedure/Results Table (60 minutes)
Day 6: Experiment/Graph/Conclusion (60 minutes)
Day 7: Poster Making/Poster Presentations (60 minutes)
Day 8: Analysis Assessment/Tie to Standards (60 minutes)

The exact module dates and times are posted on the SciTrek website (http://www.chem.ucsb.edu/scitrek/elementary) under the school/teacher. The times on the website include transportation time to and from the SciTrek office (Chem 1105). Thirty minutes are allotted for transportation before and after the module, therefore, if a module was running from 10:00-11:00 then the module times on the website would be from 9:30-11:30.

Student Groups:

For the initial observation (Day 1) students work in three groups of ~ten students each. After Day 1 the groups of ~ten students are further subdivided into three subgroups, ~four students each, to perform their experiments. Students stay in these subgroups for the rest of the module. On Day 5, subgroups will join to form “teams” (~3 subgroups per team) based on the changing variable they choose to investigate. One volunteer is assigned to help each of the groups/teams. We find groups/subgroups work best when they are mixed levels and mixed language abilities.
NGSS Performance Expectation Addressed:

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing human impact on the environment.*

Common Core Mathematics Standard Addressed:

6.RP.3.C Find a percent of a quantity as a rate per 100 (e.g., 30% of a quantity means 30/100 times the quantity); solve problems involving finding the whole, given a part and the percent.

Learning Objectives:

1. Students will know how to calculate percentages.
2. Students will know how to calculate power and that it is a measure of the energy of a system over time.
3. Students will know how to read a light bulb package to understand how much power the lightbulb produces so that they can minimize their power usage.
4. Students will know that they can only have one changing variable to draw a conclusion.
5. Students will be able to determine whether a conclusion is appropriate based on a given data set.
6. Students will be able to recognize and interpret trends in graphical data, and use that data to make predictions.
7. Students will be able to collaborate as a class to plan and carry out a focused experiment.
8. Students will be able to list at least two ways that they behaved like scientists.

Classroom Teacher Responsibilities:

In order for SciTrek to be sustainable, the program needs to work with teachers on developing their abilities to run student-centered inquiry-based science lessons on their own in their classrooms. As teachers take over the role of SciTrek lead, SciTrek will expand to additional classrooms. Even when teachers lead the modules in their own classrooms, SciTrek will continue to provide volunteers and all of the materials needed to run the module. Below is a sample timeline for teachers to take over the role as the SciTrek lead.

*Groups are made up of ~ten students and are subdivided into three subgroups (~four students), to perform experiments.

1. Year 1
   a. Classroom teacher leads a group (Role: Group Lead; this is referred to as a volunteer in these instructions)
   b. Classroom teacher co-leads the modules with a SciTrek staff member (Role: Co-Lead)
      i. Classroom teacher will be responsible for leading entire class discussions (Ex: Analysis Activity).
      ii. Classroom teacher will be responsible for time management.
      iii. Classroom teacher will be responsible for overseeing volunteers and helping any groups that are struggling.
      iv. Classroom teacher will be responsible for all above activities, the SciTrek co-lead will only step in for emergencies.
      v. The SciTrek co-lead will run the Tie to Standards Activity.
2. Year 2 and beyond
   a. Classroom teacher leads the modules (Role: Lead)
      i. Classroom teacher will be responsible for leading entire class discussions (Ex: Analysis Activity).
      ii. Classroom teacher will be responsible for time management.
iii. Classroom teacher will be responsible for overseeing volunteers and helping any groups that are struggling.

iv. A SciTrek staff member will co-lead the Tie to Standards Activity with the classroom teacher for year 3.

SciTrek staff is counting on teacher involvement. Teachers should notify the SciTrek staff if they will not be present on any day(s) of the module. Additional steps can be taken to become a SciTrek lead faster than the proposed schedule above. Contact sciTrekelementary@chem.ucsb.edu to learn more.

In addition, teachers are required to come to UCSB for the module orientation, ~one week prior to the start of the module. Contact sciTrekelementary@chem.ucsb.edu for exact times and dates, or see our website at http://www.chem.ucsb.edu/scitrek/elementary under your class’ module times. At the orientation, teachers will go over module content, learn their responsibilities during the module, and meet the volunteers that will be helping in their classroom. If you are not able to come to the orientation at UCSB, you must complete an online orientation. Failure to complete an orientation for the module will result in loss of priority registration for next year.

Prior to the Module (at least 1 week):

1. Come to the SciTrek module orientation at UCSB.

During the Module:

Note: Timing is tight on Day 7 of the module. It is possible that students will only get through two of the three presentations during the allotted time. In this case you will need to lead the third poster presentation and discuss findings outside of SciTrek sessions, before Day 8 of SciTrek.

If possible, have a document camera available to the SciTrek lead every day of the module. If you do not have a document camera, please tell the SciTrek staff at orientation.

Day 1:

Have the students’ desks/tables moved into three groups and cleared off. This ensures that each student has a desk during SciTrek activities and that students can begin the module as soon as SciTrek arrives.

Day 2-7:

Have the students’ desks/tables moved into nine groups and cleared off. This ensures that each student has a desk during SciTrek activities and that students can begin the module as soon as SciTrek arrives.

Day 8:

Have the students’ desks/tables cleared off. The desks/tables do not need to be moved into groups.

Scheduling Alternatives:

Some teachers have expressed interest in giving the students more time to work with the volunteers throughout the module. Below are options that will allow the students more time to work with the volunteers. If you plan to do any of the following options, please inform the SciTrek staff no later than your orientation date (~one week before your module, exact orientation times are found at: http://www.chem.ucsb.edu/scitrek/elementary). This will allow the SciTrek staff to provide you with all needed materials.

Day 1:
If you would like to have more time for your students to make observations and generate variables, you can do the Analysis Assessment before SciTrek arrives.

Day 2:
If you would like to have more time for your students to design their experiments, you can do the example question/experimental set-up that is outlined in the introduction before SciTrek arrives.

Day 3:
If you would like to have more time for your students to perform their experiments, you can finish the Analysis Activity after SciTrek leaves.

Day 4:
If you would like to have more time for your students to work on the Technique Activities, you can finish the Analysis Activity after SciTrek leaves.

Day 5:
If you would like to have more time for your students to collaborate and redesign their experiments, you can do finish the Analysis Activity before SciTrek arrives.

Day 7:
If you would like to have more time for your students to discuss their experiments during poster presentations, you may take more time for each presentation and finish the presentations after SciTrek leaves.

Day 8:
If you would like more time for the Tie to Standards Activity, you may give the Analysis Assessment before SciTrek arrives.

Materials Used for this Module:

1. Infared Thermometers (Amazon.com: Etekcity Lasergrip 774 IR Thermometer) Students will read the temperature to the nearest whole number. Therefore, to make it easier for them a Sharpie was used to black out the decimal places. See picture below for example.

2. Extension cords
3. Clear rulers (Amazon.com: eBoot clear plastic ruler, 12-inch/metric)
4. Wooden Rulers (Office Depot Part Number: 21215472)
5. Battery connect snaps 9V 6” leads (Digi-Key part number: BS6I-MC-ND). 22-18 gauge crimp butt connectors (pink) were used to connect ~1 inch of solid core copper with (20 gauge) to the battery connect snaps.
6. 2x1.5 V AAA Battery Holder Case Box with red and black wire. 22-18 gauge crimp butt connectors (pink) were used to connect ~1 inch of solid core copper with (20 gauge) to the battery holders (Amazon)
7. Bread board strip 1.80x1.40” (Digi-Key part number: 1738-1321-ND). To make sure the LED is oriented correctly in the breadboard, the breadboard was labelled by coloring 1 port red and 1 port black to correspond with the correct LED leg. See picture below for example.

8. Vernier KidWind 2V/400 mA Solar Panel (Fisher part number: S04828ND). Students may shade their solar panel in their experiment. To indicate the position for the shading tool, a silver Sharpie was used to make a hash mark every 0.6 cm on the sensor portion of the solar panel to break it up into 8 equal portions. Students must also take the temperature of their panel. To indicate where to take the temperature, a silver dot is drawn (using Sharpie) directly in the center of the panel. See picture below for an example. To make it easier for the students to position the solar panel, it will be placed in a circuit board holder. To indicate where to place the panel in the holder, a silver Sharpie was used to color in rectangles on either side of the panel between the 4/8 and 7/8 markers. See the picture below (left) for an example.

9. Cardboard for shading. In order to shade the solar panel, cardboard pieces (11.6 cm long × 6 cm wide) were cut. Using a black Sharpie, a line was drawn from top to bottom at 5.5 cm. The longer side was labelled with an “L” for “left” and the shorter side was labelled with an “R” for “right.” Starting from the top, 1 small line was drawn at 0.5 cm. From there, 4 lines were drawn every 0.6 cm. Each of those lines was then extended 1 cm on either side of the center line and labelled with a fraction (5/8 – 8/8). On each of those 2 cm long lines, a silver Sharpie was used to put a dot in the center of the line to signify that the temperature would be taken at each of those shading amounts. The shading tools were then laminated so they will last longer. See example above (right).
   a. We used the back of a poster paper pack, but any thin cardboard will work

10. Golden Apple, 5.5 oz black plastic jello shot souffle cups with clear lids, sampling cup (Amazon). To make the LED light easier for students to see, these cups were modified to hold the LEDs by drilling a \( \frac{11}{64} \) hole directly in the center of the cup. The LED was placed inside and hot glued to the base of the cup. See picture below for example.

11. LEDs. To ensure that LEDs are oriented correctly in the breadboard and when being clamped to the solar panel, the long leg was colored red to correspond to either the red port (breadboard) or red lead
(solar panel) and the short leg was colored black to correspond to either the black port (breadboard) or black lead (solar panel). See picture above (left) for example. Additionally, to make the LED light easier to see, some LEDs were hot glued into the plastic cups. See picture below for example.

a. White LED, 5 mm, 3.4 V, 20 mA, lens colorless, through hole (Digi-Key part number: 160-1772-ND)

b. Green LED, 5 mm, 2.1 V, 20 mA, lens green, through hole (Digi-Key part number: 160-1702-ND)

c. Red LED, 5 mm, 2 V, 20 mA, lens red, through hole (Digi-Key part number: 160-1701-ND)

d. Blue LED, 5 mm, 3.5 V, 20 mA, lens color colorless, through hole (Digi-Key part number: 160-1610-ND)

12. Aven 1710 Adjustable Circuit Board Holders (amazon). These holder have been modified by adding four, 2 in, mending braces (Ace part number: 5292040). One brace goes on the inside of the holder and the other three braces go on the outside of the holder. The braces are heled to the circuit board holder with two hex bolts (1/4 x 1 1/4) and two hex nuts (1/4). The height of the mending braces are adjusted so that the origin of the swing arm protractor sits at the rotation point of the circuit board holder. See picture below.

13. Spacing tool. To ensure the light is the correct distance from the solar panel, cardboard rectangles (14 cm long × 4.5 cm wide) were cut. Any thicker cardboard box will work.
14. Conair 1600 Watt compact hair dryer with folding handle; dual voltage travel hair dryers (Amazon)
15. 15 mm Binder clips
16. Light bulbs
   a. Ecosmart LED bulb (50-Watt Equivalent BR20 Dimmable CEC LED Light Bulb Daylight), 550 lumens, 120 V, 7 watt, 5000 K, 550 lumens (Home Depot part number: 1002965665)
   b. Ecosmart compact florescent (40-watt equivalent E26 Spiral CFL Light Bulb Daylight (2-Pack), 120 V, 9 watt, 5000 K, 500 lumens (Home Depot part number: 252763)
   c. Philips, halogen bulb (40-Watt halogen clear decorative globe light bulb (3-pack)), 120 V, 40 W
17. Amp meter singstek UT210E handheld RMS AC/DC Mini Digital Clamp Meter Resistance Capacitance Tester (Amazon)
18. AstroAI Digital Multimeter with Ohm Volt Amp and Diode Voltage Tester Meter (Intelligent Anti-burn) (Amazon). Students will only read the current to the tenths place. Therefore, to make it easier for them, a Sharpie is used to black out the hundredths place. Additionally, to ensure that we get appropriate current readings between 0-20 mA, a black Sharpie is used to box the 20m setting on the multimeter. To ensure we get appropriate voltage readings between 0-20 V, a silver Sharpie is used to box the 20 setting on the multimeter. See picture below for example.

19. TOTOT Banana Plug to Alligator Clip 1 Red 1 Black Test Leads 15A Safe Plug (Amazon)
20. Cable Matters 2-Pack Hanging Light Cord (Light Socket with Cord) with On Off Toggle Switch in Black - 15 Feet. In order to measure the current flowing through one the wires, the double wires must be split in half on a portion of the wiring, as shown below.
21. Tensor 367898 Tensor Compact Fluorescent (CFL) Desk Lamp 20-Inch H Black (13061-005) (These can also be purchased from Carolina Biological Supply)
   All printed materials used by SciTrek (student notebooks, materials pages, team plan page, lead picture packet, poster parts, instructions, and nametags) can be made available for use and/or editing by emailing scitrekelementary@chem.ucsb.edu.

**Types of Documents:**

**Student Notebook:**
One given to every student and is filled out by the student. In these instructions, the examples are rectangular and filled out in black. The lead will use a student notebook to write in as an example for students. The notebook that the lead uses is referred to as the class notebook in these instructions.

**Notepad:**
One given to every group and is filled out by the volunteer. In these instructions, the examples are squarer and filled out in blue.

**Picture Packet:**
One per class that, if needed, the lead fills out. In these instructions, the examples are rectangular, labeled, and, if applicable, filled out in blue.

In these instructions, all other example documents are labeled.

**Day 1: Analysis Assessment/Observations/Technique/Variables**

**Schedule:**

- Introduction (SciTrek Lead) – 2 minutes
- Analysis Assessment (SciTrek Lead) – 15 minutes
- Observation Discussion (SciTrek Lead) – 2 minutes
- Observations (SciTrek Volunteers) – 13 minutes
- Technique (SciTrek Lead) – 12 minutes
- Variable Discussion (SciTrek Lead) – 5 minutes
- Variables (SciTrek Volunteers) – 9 minutes
- Wrap-Up (SciTrek Lead) – 2 minutes

**Materials:**
### Volunteer Boxes:

- ☐ Student nametags
- ☐ (12) Student notebooks
- ☐ Volunteer instructions
- ☐ Picture of experimental set-up
- ☐ Volunteer lab coat
- ☐ (2) Pencils
- ☐ (2) Wet erase markers
- ☐ (2) Rulers
- ☐ (12) Clear rulers
- ☐ Solar panel
- ☐ Solar panel holder
- ☐ IR thermometer
- ☐ Hair dryer
- ☐ Multimeter
- ☐ Spacing tool
- ☐ Shading tool
- ☐ (2) binder clips
- ☐ Protractor
- ☐ Cup with red LED
- ☐ Cup with blue LEDs

### Other Supplies:

- ☐ (3) Large group notepads
- ☐ Calculator box
- ☐ Box of 4 lamps with 4 extension cords
- ☐ (3) Large group notepads
- ☐ (2) Wet erase markers
- ☐ (3) Markers (orange, blue, green)
- ☐ (2) Ruler
- ☐ (5) Clear rulers
- ☐ (2) Solar panels
- ☐ Solar panel holder
- ☐ IR thermometer
- ☐ Hair dryer
- ☐ (2) Multimeters
- ☐ Spacing tool
- ☐ Shading tool + 2 binder clips
- ☐ (3) Protractors
- ☐ Container with 3 red LEDs
- ☐ Container with 3 blue LEDs
- ☐ Breadboard
- ☐ 1 AAA battery pack with batteries
- ☐ 1 9 V battery pack with battery
- ☐ 2 extra AAA batteries
- ☐ 1 extra 9 V battery

### Lead Box:

- ☐ (3) Blank nametags
- ☐ (3) Extra student notebooks
- ☐ Lead instructions
- ☐ Solar Power picture packet
- ☐ Picture of experimental set-up
- ☐ Lead lab coat
- ☐ (35) Analysis Assessments
- ☐ Time card
- ☐ (2) Pencils
- ☐ (2) Wet erase markers
- ☐ (3) Markers (orange, blue, green)
- ☐ (2) Ruler
- ☐ (5) Clear rulers
- ☐ (2) Solar panels
- ☐ Solar panel holder
- ☐ IR thermometer
- ☐ Hair dryer
- ☐ (2) Multimeters
- ☐ Spacing tool
- ☐ Shading tool + 2 binder clips
- ☐ (3) Protractors
- ☐ Container with 3 red LEDs
- ☐ Container with 3 blue LEDs
- ☐ Breadboard
- ☐ 1 AAA battery pack with batteries
- ☐ 1 9 V battery pack with battery
- ☐ 2 extra AAA batteries
- ☐ 1 extra 9 V battery
Notebook Pages and Notepad Pages:

**OBSERVATIONS**

Experimental Set-Up:
- Thermocouple
- Hair dryer
- Room temperature + 2°C

Other observations of the experimental set up:
- The received the solar panel to 30°C with the hair dryer.
- We measured the current and voltage using the multimeter.

**Solar Panel Measurements**

<table>
<thead>
<tr>
<th>Current (mA)</th>
<th>Voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2mA</td>
<td>1.9V</td>
</tr>
</tbody>
</table>

When the red LED was hooked up to the solar panelit did not light.

When the blue LED was hooked up to the solar panel it did not light.

**TECHNIQUE**

Calculating Power

One way to measure the energy of our system over time is by calculating the power of the system. Power (P) can be found by multiplying the current (I) measured in milliamperes (mA) and voltage (V) measured in volts (V) of the system together:

\[ P = I \times V \]

For this experiment, power is calculated in units called milliwatts (mW).

**Directions:** Calculate the power produced by each system. Round your answer to the nearest tenth (Ex: 9.5 mW).

<table>
<thead>
<tr>
<th>a) Class solar panel</th>
<th>b) Your solar panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>I = 2.9mA</td>
<td>I = 5.2mA</td>
</tr>
<tr>
<td>V = 1.8V</td>
<td>V = 1.9V</td>
</tr>
<tr>
<td>P = 2.9mA \times 1.8V</td>
<td>P = 5.2mA \times 1.9V</td>
</tr>
<tr>
<td>= 5.28mW</td>
<td>= 9.84mW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c) Round batteries</th>
<th>d) Rectangular battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>I = 20mA</td>
<td>I = 1 mA</td>
</tr>
<tr>
<td>V = 1.8V</td>
<td>V = 6.1V</td>
</tr>
<tr>
<td>P = 20mA \times 1.8V</td>
<td>P = 1mA \times 6.1V</td>
</tr>
<tr>
<td>= 36.0mW</td>
<td>= 6.1mW</td>
</tr>
</tbody>
</table>

1. What does our experiment tell us about the red and blue LEDs?
   - They require a certain amount of power to work.

2. What happens when the red LED is hooked up to the round batteries?
   - It lights up.

3. What happens when the blue LED is hooked up to the rectangular battery?
   - It lights up.

4. Why does this happen?
   - Too much power has applied.

5. What do we call about objects that require specific conditions and too much power can be harmful?
   - They are called under specific conditions.

6. How can we monitor the amount of power used by a device? We can measure the current and voltage to calculate power usage.
Preparation:

SciTrek Lead:
1. Make sure volunteers are writing their name and group color on the whiteboard.
2. Make sure volunteers are passing out nametags.
3. Make sure volunteers are setting up for the initial observation.
4. If the classroom has a document camera, ask the teacher to use it for the Analysis Assessment, Technique Activity (page 3, student notebook), and the class question (front cover, student notebook). If the classroom does not have a document camera, then write the class question on the board during the variable discussion.
5. Set up the lead set-up.
   a. Place a solar panel in the solar panel holder, turn the angle to 45°, and use the shading tool to shade $\frac{2}{8}$ of the panel.
   b. Hook the multimeter up to the panel.
   c. Place the AAA battery pack, 9V battery, and breadboard near the lead set-up.

SciTrek Volunteers:
1. On the front whiteboard in the classroom, write your name and the color of the group (orange, blue, or green) you will be working with.
2. Pass out nametags.
   a. Assemble the experimental set-up (shown in picture below as well as in color in the experimental set-up picture in your group box). Place the shading tool on the solar panel at $\frac{2}{8}$ shaded and clamp on both sides using the binder clips.
   b. Set the solar panel in the solar panel holder by aligning the silver rectangles on the panel with the clamps on the holder. The solar panel should be at a 0° angle (flat, parallel to tabletop).
   c. Place the solar panel set-up under the center of the lamp and use the spacing tool to position the lamp 14 cm above the center of the panel.
i. The spacing tool is exactly 14 cm long. Place one end in the middle of the solar panel and the other touching the lowest part of the lamp.

d. Set the protractor on the metal ledge on the side of the holder and rotate the solar panel to 45°.
   i. Use the colored scale on the protractor when measuring the angle of the panel.

e. Attach the multimeter to the solar panel by connecting the red wire of the multimeter to the red wire of the solar panel and the black wire of the multimeter to the black wire of the solar panel

f. Place the infrared (IR) thermometer, hair dryer, and rulers on the table next to the set-up.

g. Have the red LED and blue LED cups in your lab coat pocket to use at the end of the observation section.

**Introduction:**
(2 minutes – Full Class – SciTrek Lead)

If they have not done so already, have volunteers write their name and group color on the front whiteboard and then get student nametags out of their group boxes and walk around the room quietly setting each student’s nametag on their desk. After, they should assemble the experimental set-up.

For UCSB Lead:
“Hi, we are scientists from UCSB and we want to show you what we do as scientists. We will show you an experiment and then you can make observations, come up with a class question, and design your own experiment to help answer the class question. We want to show you that you can do science and have fun.”

For Teacher Lead:
“I have asked some scientists from UCSB to come and help us with a long-term science investigation. We will make observations, come up with a class question, and you will design your own experiment to help answer the class question.”

Allow the UCSB volunteers to introduce themselves and share their majors.

**Analysis Assessment:**
(15 minutes – Full Class – SciTrek Lead)

“Before we start with the module, we will determine how your ideas on analyzing and interpreting data are developing.” Pass out the Analysis Assessment and tell students to fill out their name, teacher’s name,
and date at the top of the assessment. Remind the students that it is important that they fill out this assessment on their own.

For page 1, read the directions for annotating to the students. Then, have students annotate the first results table by underlining controls, circling changing variables, and boxing in information about data collection. Read question 1b (Can this group make a conclusion?), and have students answer it. Have students annotate the possible conclusion. Finally, read question 1d (Is this a correct conclusion for the results table? If NO what is wrong with the conclusion?) and have students answer the question. Repeat this process for questions 2 and 3.

Pass out the rulers to students. For question 4, show students how to annotate the graph. First, ask students, “What is on the x-axis (the horizontal)?” Students should reply, “Time.” Tell students that the changing variable will always be found on the x-axis, so we should circle “time.” Ask students, “Where else do they see “time” on this graph?” They should reply, “In the title.” Circle time in the graph title. Then ask students, “What is being measured on the y-axis (vertical)?” They should reply, “Distance traveled.” Tell students that data (measurements/observations) will always be found on the y-axis, and box “distance traveled.” Then ask students, “Do you see “distance traveled” anywhere else on the graph?” They should also notice the data in the graph title, and box “distance a ball travels.” Finally, point out the “amount of sand” is a special type of control that they will learn about later in the module. Underline “amount of sand” in the legend and ask if this appears anywhere else on the graph. Underline “amount of sand” in the graph title.

Students should answer the remaining questions on their own. Have students plot the remaining points on the graph using circles as markers. Then tell students to draw trend lines for each experiment on the graph. Read questions 4d-4f and give students time to answer each. Walk around to make sure students are filling out the questions. After reading the last question, tell students to raise their hands when they are finished so you can collect their assessments and clear rulers.

**Observation Discussion:**
*(2 minutes – Full Class – SciTrek Lead)*

Have volunteers pass out a notebook to each student.

Have students fill out their name, teacher’s name, group color (color of their name on their nametag: orange, blue, or green), and their volunteer’s name (volunteers’ names should be written on the board next to the group color they will be working with) on the front cover of their notebooks. Students will leave the subgroup number, subgroup symbol, and class question blank. If a student does not have a nametag, only have them fill out their name and teacher’s name on the cover of their notebook. They will be placed in a group when the class divides into groups for observations and they can fill out their group color and volunteer at that point.

Tell the students that scientists make many observations. Ask the class, “What is an observation? What are the types of things that you can record for an observation?” If they have trouble, show them an object and let them make some observations. Turn these specific observations into general features of an observation. Examples of possible general observations are: color, texture, size, weight, temperature, material, etc. Lead students to understand that an observation is a description using your five senses.

Tell students, “In this experiment we are going to make observations of a solar panel.” Ask the class, “Do you know what solar panels are used for?” Lead students to understand that solar panels take energy from the sun and transfer it to electrical energy for us to use.
Tell students that one of the scientific devices that we will be using is a multimeter. Put a multimeter under the document camera. Multimeters are tools that measure the amount of current and voltage being produced/used by an object. We will measure current in milliamps and voltage in volts. Tell students that in order to record the current, students will turn the dial to the setting that is boxed in black and in order to record the voltage, students will turn the dial to the setting that is boxed in silver. Explain that later you will show them how to calculate the energy per time from given current and voltage measurements, but for now they should know that the more current and voltage the solar panel produces, the more electricity it produces.

Tell the class they will now get in their groups and make observations. Tell each colored group where to go and to bring a pencil and their notebook.

If a student does not have a nametag, identify the group with the least number of students in it and write the student’s name on one of the extra nametags that are in the lead box using that color of marker.

**Observations:**
(13 minutes – Groups – SciTrek Volunteers)

Once the students come over to your group, have them sit in boy/girl fashion. Verify the materials are set up as described in the Set-Up Section. Have student turn to page 2 in their notebook.

As a group, have the students tell you what they observe in the experimental set-up. Then draw and label a picture of the item in the provided box on the group notepad while student copy the information into their notebooks. Other observation that are not in the picture should be recorded under “other observations of the experiment set-up.” Students can move the solar panel to take measurements about its placement. The students will most likely not know what the IR thermometer is since it doesn’t look like a traditional thermometer. Demonstrate how to use the thermometer by pointing it perpendicular (90°) to the solar panel and holding down the trigger so the laser shines on the silver dot in the center of the solar panel. Allow students to read the measurement and record the room temperature. This should take you no longer than 7 minutes.
When you are ready to start the experiment, make sure the solar panel is returned to its original position as described in the Set-Up Section. Tell students that we are now going to run an experiment to determine the amount of current and voltage produced by the solar panel in its current position. Have students remind you what we use to measure the current and voltage (a multimeter) and in what units each value is measured in (milliamps for current, volts for voltage). Turn on the lamp. Assign one student to read the current and voltage from the multimeter. Have the student turn the multimeter to the setting boxed in black, this will allow them to measure the current first. Tell them that you will inform them when solar panel is at the correct temperature and they can read out the current and then change the multimeter to the setting that is boxed in silver and read out the voltage.

Put the hair dryer on high and hold it about 6 inches from the panel. Heat the panel for approximately 10 s. Remove the hair dryer from the solar panel and use the thermometer check the temperature. If the temperature is below 30° heat the solar panel for approximately 10 s more and recheck the temperature. Continue doing this until the solar panel is 1° or 2° over 30°. Then wait for the panel to cool to 30° and have the student tell the group the current and voltage produced. Record these values on the group notepad while students copy them into their notebook. Then have students write one sentence about what you did during the experiment.

Tell students that one thing that electricity can be used for is to light lightbulbs. Therefore, we will look at if our solar panel can light a red and a blue LED bulb. Unhook the alligator clamps connecting the multimeter to the solar panel and set the multimeter to the side. Take the red LED cup and connect it to the solar panel. The leg colored in red on the LED (long leg) should connect to the red wire of the solar panel and the leg colored in black on the LED (short leg) should connect to the black wire of the solar panel. Connect the alligator clamps on the uncolored portion of the LED legs. The red LED should light. Shine the light directly at each of the students to make sure they can see the LED lit up. If they are having trouble, place your hand over the solar panel to block the light (the LED should unlight) and remove your hand (the LED should light). Unhook the red LED and attach the blue LED in the same manor to the solar panel. The blue LED should not light. Again, make sure that each student sees the unlit LED. Unhook the LED and set it aside. Have students answer the two questions on the bottom of page 2.
If there is additional time, have students make predictions about why the blue LED did not light.

An example filled out initial observations is shown below.

**Technique:**  
(12 minutes – Full Class – SciTrek Lead)

Ask the class, “What did you do in their experiment?” Possible student response: we set the solar panel to an angle of 45°, turned on the light and heated the solar panel to a temperature of 30°C. Then we measured the amount of current and voltage produced by the solar panel. We saw that this energy could light a red LED but not a blue LED.

Tell students, “In your experiments you measured the current and voltage and I will now show you how to turn these measurements into a scientific quantity called power. Power is the amount of energy per time
that a device is using or supplying. Power can be calculated by multiplying the current in milliamps and voltage in volts. When this is done the units of power are milliwatts.” Have students turn to page 3 in their notebooks as you place the class notebook opened to page 3 under the document camera. Have the volunteers pass out one calculator to each student.

Read the directions on page 3 to students (calculate the power produced by each system. Round your answer to the nearest tenth). Tell students that as an example, we will calculate the power produced by a class solar panel. Show students the class solar panel (this panel will not be under a lamp, you will just use the room light to generate energy). The class solar panel should be set up close enough to the document camera so the multimeter can be placed under it. Turn the dial on the multimeter to the setting boxed in black to measure the current. Tell students that current is represented by the letter I, then record the current value in the class notebook under letter a and have students copy it into their notebook. Turn the dial to the setting boxed in silver and have students read the voltage produced by the solar panel. Tell students that voltage is represented by the letter V, then record this number in the class notebook under letter c, and have students copy it into their notebook. Tell students, “Now that we have the current and the voltage, we can use our calculators to determine the power produced by the solar panel.” In the class notebook show students how to set up their equation \( P = I \times V \). Write the current value and units (Ex: 0.5 mA) in the first blank and the voltage value and units (Ex: 1.5 V) in the second blank. Place a calculator under the document camera and show students how to input the operation into the calculator and solve for the power. Tell students that we want to round our answer to the nearest tenth, which means we only want one number after the decimal. Have students tell you the value of the power we should record, as well as the units for power (milliwatts), and then write the power value and units in the blank (Ex: 0.8 mW).

Tell students that they should calculate the power from their group’s solar panel on their own and record their answer for letter b. Have the volunteers calculate the power of the solar panel for their group to the nearest tenth and check with their students to make sure they calculated the same value. They should also check to make sure students are setting up their calculations properly and including the appropriate units.

Pull the class back together and tell them you will now measure the current and voltage of a battery pack that contains two round batteries (AAA). Hook up the battery pack to the multimeter and place the multimeter under the document camera. Turn the dial to the setting boxed in black and have the students read the current in milliamps. Record the current in the class notebook under letter c as students record it in their notebook. Turn the dial to the setting boxed in silver and have the students read the voltage in volts. Record the voltage in the class notebook under letter c as students record it in their notebook. Have students calculate the power of the round batteries, then have them share out the power and record it in the class notebook.

Tell students you will also measure the current and voltage of a rectangular battery (9 V). Hook up the battery to the multimeter and place the multimeter under the document camera. Turn the dial to the setting boxed in black and have the students read the current in milliamps. Record the current in the class notebook under letter d as students record it in their notebook. Turn the dial to the setting boxed in silver and have the students read the voltage in volts. Record the voltage in the class notebook under letter d as students record it in their notebook. Have students calculate the power of the rectangular battery, then have them share out the power and record it in the class notebook.

Have students remind you what happened when they hooked the red and blue LEDs to their solar panel. Possible student response: the red LED lit and the blue LED did not. Have students predict what will happen when you attach the blue LED to the round batteries and allow a few students to share their ideas with the class. Take out the breadboard, place it under the document camera, and attach the round battery pack to the indicated ports (see example picture below). Take the blue LED and insert the legs into
the corresponding ports. The red colored leg (long leg) should be placed into a port along the same row as the red wire. The black colored leg (short leg) should be placed into a port along the same row as the black wire (see example picture below). The LED should light up.

![Image of LED and battery](image.png)

Red wire to any port along red row
Black wire to any port along black row

Have students predict what will happen when you attach the blue LED to the rectangular battery and allow a few students to share out their ideas with the class. Take the LED out of the breadboard and detach the round battery pack. Attach the rectangular battery to the breadboard in the same way as the round battery pack (red wire to red port and black wire to black port). Insert the LED in the same manner as before. The LED should blow immediately. Quickly take it out of the breadboard and hold it closely under the document camera so students can see inside of the LED.

![Image of LED being touched to battery](image.png)

Ask students, “What happens when the blue LED is touched to the rectangular battery?” Possible student response: it blows up. Ask students, “Why do you think this happened?” Lead students to understand that too much power was applied to the LED, which caused it to blow up. Have students answer questions 1 through 6 individually and then have them share out their answers and write the class consensus answer in the notebook.
Tell students, “Now that we know how to calculate the energy per time, or the power, we can investigate the question: What variables affect the amount of power produced by a solar panel?” Have students turn to the front cover of their notebooks as you turn to the front cover of the class notebook under the document camera. Fill in the class question (What variables affect the amount of power produced by a solar panel?)

**Variable Discussion:**

*(5 minutes – Full Class – SciTrek Lead)*

Ask the students the following questions:
- What does the word “variable” mean to a scientist? (variables are the parts of the experiment that you can change)
- Do you think that there are multiple variables that will affect the power produced by the solar panel? (multiple variables might affect the power produced by the solar panel)

Tell the class that they are going to think about variables in the experiment that they could change to help us answer the class question. In addition to generating variables, they should think about how/why these variables might affect the outcome of the experiment. Ask the class, “What do you think is a variable that might affect the power produced by the solar panel?” Then, have them tell you how/why they think that variable would affect the experiment. Probe them on how they would design an experiment to test if this variable affected the power output. Finally, have the students make a prediction of the results for the experiment they proposed. Remind students that predictions can be wrong, and we will not know the correct answers until we carry out the experiment.

Ex: **Variable:** panel angle
Why might this variable affect the power produced by the solar panel? Solar panels that are less angled (closer to a 0° angle) will receive more light which would lead to more power being produced.

How would you test this variable? Place the solar panel at different angles and track the current and voltage being produced.

Prediction: The less angled the panel, the larger the power produced.

Tell students they will now generate more variables and analyze them in their groups.

**Variables:**
(9 minutes – Groups – SciTrek Volunteers)

As a group, generate a variable and make a prediction about how it will affect the power produced by the solar panel. Encourage and challenge students to explain why they think their prediction is correct and how this variable will affect the power produced by the solar panel. Repeat this process two more times, record these ideas on the group notepad, and have students copy them into their notebooks. If students have different predictions, they can write their own predictions in their notebooks. Next, students will individually generate additional variables, make predictions about how different values of this variable will affect the power produced by the solar panel, and record their ideas in their notebooks. Have students share these ideas with the group.

Prepare one student to share a variable and why they think it will affect the power produced by the solar panel during the class discussion.

<table>
<thead>
<tr>
<th>Variable</th>
<th>How changing this variable affect the power produced by the solar panel?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel Angle</td>
<td>If the panel is flatter (closer to a 0° angle), more power will be produced.</td>
</tr>
<tr>
<td>Light Brightness</td>
<td>Brighter light will cause the solar panel to produce more power.</td>
</tr>
<tr>
<td>Light Source</td>
<td>Natural light (like the sun) will cause more power to be produced.</td>
</tr>
<tr>
<td>Temperature</td>
<td>Higher temperatures might cause less power to be produced because the solar panel may break down.</td>
</tr>
<tr>
<td>Water Amount</td>
<td>Adding water over the solar panel (to simulate rain) will cause the solar panel to have less available space to catch light, producing less power.</td>
</tr>
</tbody>
</table>

Choose your own!
Wrap-Up:
(2 minutes – Full Class – SciTrek Lead)

Have one student from each group share a variable that they generated and how/why they think it will affect the power produced by the solar panel. Make sure that students tell you their predictions about how different values of that variable will affect the power produced by the solar panel.

Tell students that the next session they will design an experiment to answer the class question: What variables affect the amount of power produced by a solar panel?

Clean-Up:

1. Collect students’ notebooks with attached nametags.
2. Place calculators back in the carrier.
3. Place all materials into your group box.
4. If you would like to divide your group (“ten students) into three subgroups, you can do this by writing a “1,” “2,” or “3” on the top of each student’s notebook to designate their subgroup.

Day 2: Question/Materials Page/Experimental Set-Up/Procedure/Results Table

Schedule:

Introduction (SciTrek Lead) – 14 minutes
Question (SciTrek Volunteers) – 7 minutes
Materials Page (SciTrek Volunteers) – 7 minutes
Experimental Set-Up (SciTrek Volunteers) – 8 minutes
Procedure (SciTrek Volunteers) – 18 minutes
Results Table (SciTrek Volunteers) – 3 minutes
Wrap-Up (SciTrek Lead) – 3 minutes

Materials:

(3) Volunteer Boxes:
☐ Student nametags
☐ Student notebooks
☐ Volunteer instructions
☐ Volunteer lab coat
☐ (3) Experiment 1 materials pages (subgroup color & number indicated)
☐ (2) Pencils
☐ (2) Red pens
☐ Notepad

Lead Box:
☐ (3) Blank nametags
☐ (3) Extra student notebooks
☐ Lead instructions
☐ Solar Power picture packet
☐ Lead lab coat
☐ (3) Experiment 1 materials pages
☐ Time card
☐ (2) Pencils
☐ (2) Red pens
☐ (2) Wet erase markers
☐ (3) Markers (orange, green, blue)
☐ Notepad
☐ Shading tool + 2 binder clips
☐ Solar panel
Experimental Considerations:

1. You will only have access to the materials on the materials page.
2. See materials page for restrictions on experimental design.

Changing Variable(s) (Independent Variable(s))

You will get to perform two experiments. For your first experiment decide which variable(s) (max two) that you would like to test. For each changing variable that you select, discuss with your group why you think that variable will affect the power produced by the solar panel.

Changing Variable 1: Panel angle
Discuss with your group how you think changing variable 1 will affect the power produced by the solar panel.

Changing Variable 2 (optional): Temperature
Discuss with your group how you think changing variable 2 will affect the power produced by the solar panel.

Question:

- If we change the panel angle and temperature, what will happen to the \( \text{amount of power produced by the solar panel} \)?

Get a materials page from your SciTrek volunteer and fill it out before moving onto the experimental set-up.

---

### PROCEDURE

1. Place shading tool over solar panel at \( 45^\circ \) shade, and put solar panel into solar panel holder.
2. Set panel angle to \( 30^\circ, 60^\circ, 90^\circ \), and \( 120^\circ \).
3. Place solar panel directly under lamp, and turn lamp on.
4. Heat the solar panel to \( 12^\circ, 30^\circ, 44^\circ \), and \( 56^\circ \).
5. Measure the current in mA and the voltage in V produced by the solar panel using a multimeter.
6. Calculate the power produced by the solar panel by multiplying the current and voltage.

---

### RESULTS

Fill out the chart for each of your trials. For the variables that remain constant, write the value in trial A and then draw an arrow through each box indicating that the variable is a control. Remember to record data measurements to the nearest tenth (Ex: 4.4 mA).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Trial A</th>
<th>Trial B</th>
<th>Trial C</th>
<th>Trial D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Source</td>
<td>Solar panel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panel Angle</td>
<td>(30^\circ)</td>
<td>(90^\circ)</td>
<td>(45^\circ)</td>
<td>(60^\circ)</td>
</tr>
<tr>
<td>Shading Amount</td>
<td>(45^\circ)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>(12^\circ)</td>
<td>(30^\circ)</td>
<td>(44^\circ)</td>
<td>(56^\circ)</td>
</tr>
<tr>
<td>Lamp Source</td>
<td>Lamp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predictions</td>
<td>Trial A</td>
<td>Trial B</td>
<td>Trial C</td>
<td>Trial D</td>
</tr>
<tr>
<td>Power (W)</td>
<td>S</td>
<td>L</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The independent variable(s) (cm) are the changing variable(s) and the dependent variables are the current, voltage, and power.
**Preparation:**

**SciTrek Lead:**

1. If the classroom has a document camera, ask the teacher to use it for the question (page 5, student notebook), experiment 1 materials page (lead box), experimental set-up (page 6, student notebook), and results table (page 8, student notebook). If the classroom does not have a document camera, then tape the example poster-size notebook pages to the front board.

**SciTrek Volunteers:**

Set out student notebooks to allow students in the same subgroup (same number on front of notebook) to work with each other.

- If students are not in the classroom before SciTrek starts, set out the notebooks where students should sit when they come into the classroom.
- If students are in the classroom before SciTrek starts, set out the notebooks where students should sit during the module; they will move to these spots after the introduction.

Make sure you have three experiment 1 materials pages, each filled out with a subgroup number (1, 2, or 3) and your group’s color. These will be given to students after they complete their question.

Have a red pen available to approve students’ question, experimental set-up, and procedure (pages 5, 6 and 7).

**Introduction:**

(12 minutes – Full Class – SciTrek Lead)

If needed, while you are doing the introduction have volunteers set out the notebooks/nametags where they would like students to sit. Make sure that students in the same subgroup are sitting next to each other. Tell students that a notebook will be put on their desk, which is not their notebook and they should not move it.

Ask students, “What did we do during our last meeting?” Possible student response: we measured the current in milliamps and the voltage in volts produced by a solar panel. We then learned that multiply the current and the voltage give you the power produced by the solar panel or the energy per time. If the power is too high or too low a device will not work. In addition, we generated variables that might affect the power produced by the solar panel. Ask the class, “What is the class question we will be investigating?” Students should reply, “What variables affect the power produced by a solar panel?”

Tell students that one way scientists answer questions is by performing experiments; today they will design an experiment to help answer the class question. Ask the class, “Do you think there are multiple variables that could affect the power produced by the solar panel?” Possible student response: there are probably multiple variables. Therefore, each subgroup is going to generate a smaller question to investigate. Once we put all the subgroups’ research together, we should be able to answer the class question.

Subgroups will first generate a question based on the changing variable(s) that they plan to explore. They will then fill out their experiment 1 materials page, which will allow them to determine their experimental set-up. The experimental set-up will help them generate a procedure, or a set of steps to conduct an experiment. Tell students that they need to keep a few things in mind when they are going through this process.
Experimental Considerations:
1. You will only have access to the materials on the materials page.
2. See the materials page for restrictions on experimental design.

Tell students we are now going to generate an example question/experimental set-up together and that you will write it in the class notebook so that they will be able to refer back to it when they are completing the process themselves. Make sure that students DO NOT fill out the example question/experimental set-up in their notebooks.

Tell students for the example experiment, the changing variable will be: pick any variable (Ex: temperature), then write down the changing variable on the class notebook (page 5, student notebook) under the document camera. Tell students when they are going through this process in their subgroups, they can select one or two changing variable(s).

Show students how to insert the changing variable(s) and what they plan to measure/observe into the question frame to find the question that will be investigated. If we change the temperature, what will happen to the amount of power produced by a solar panel? Explain to students that many times when there is a large question, like our class question, scientists break it down into smaller questions that individual scientists can investigate, and then they compile their work to answer the large question.

Tell them once they have determined their question and have approval, their SciTrek volunteer will give them an experiment 1 materials page for determining the values of their changing variable(s) and controls. Ask students, “What is a control?” Make sure that by the end of the conversation students understand that controls are variables that are held constant during an experiment. For example, if the panel angle was 50° for all of the trials, then one of their controls would be panel angle. These controls and control values can be different from the original experiment that they conducted on Day 1, but must remain constant throughout all the trials that they do for this experiment.
Show students the experiment 1 materials page and read the first step (For each bolded word, underline if it is a control and circle if it is a changing variable). Then have students tell you what to do for each bolded word. Read steps 2 and 3 on the experiment 1 materials page (For variables that are controls, choose 1 value and write it in the first blank. For variables that are changing variables, choose 4 values and write the trial letter under each value.). Read the general materials to students, ask them if they need each one, and check the box when they say yes. When you get to “spacing tool,” show them the pre-measured piece of cardboard labeled “14 cm” that is in the lead box and tell them it will be used to quickly measure the distance from the center of the solar panel to the light bulb.

Go through the remaining items on the experiment 1 materials page. If a variable is a control, then choose (do not let students choose) a single value, such as the original value (Ex: 45° for panel angle). Assign each control value to a student and tell them they are in charge or remembering that control and value to help when filling out the experimental set-up. For variables that are changing variables, allow students to choose the values Write the trial letter under each selected value. Ask students, “Do we want a narrow or wide range of values for the changing variable, and why?” Guide students through selecting a wide range of values for the changing variable. If they choose a value contrary to their proposed experimental design, question them on their reasoning. For example, if they said they wanted to use a wide range of temperatures and they picked 30°C, 32°C, 34°C, and 37°C ask them if these values would allow them to best answer their question. Allow them to change their values if needed. Make sure students understand that for temperature, they can choose room temperature as a potential value. If they choose to use room temperature, they will record “RT” in the blank and on experiment day, they will measure the actual temperature in the classroom.

Tell students that once they have completed their materials page, they will fill out their experimental set-up (page 6, student notebook). First, they will fill out the information on the changing variable(s). Ask students, “What is the changing variable for our example experiment and what values did we select?” Then, fill in the values for trial A and B only. Second, they will fill in information about the controls. Draw in an additional control line under the existing control list. Ask students, “What is one of our controls and
its value for the example experiment?” Show students how to record the control on the left side of the slash (Ex: panel angle) and the value of that control on the right side of the slash (Ex: 30°). There are three possible variables to choose from on the materials page. If a subgroup changes two variables, they will be left with one control blank empty after putting in the information from the materials page. Since all control blanks must be filled out, tell students that they may need to generate an additional variable that does not come from the materials page. Lead students to realize this should be light source/lamp.

Tell students that after they finish their experimental set-up, they will write a procedure for their experiment that they will be able to follow next time. When writing a procedure, they should write all the values of their changing variable(s) and controls as well as what data will be collected. Show students the example procedure step on the top of page 7 of their notebook (Place the panel at an angle of A) 30°, B) 45°, C) 60°, and D) 75°). Once the procedure is completed, they will get it approved by a SciTrek volunteer.

Tell students after they write their procedure they will fill out their results table. On their results table they should underline controls, circle change variables, and box information about data collection. For controls, they will write the value in trial A and then draw an arrow through the remaining trials and for the changing variable(s), they will write the value in each box. Tell students that once they have filled out the results table, they will make predictions about which trial will produce the smallest and largest power. They will write an “S” in the box of trial that they think will produce the smallest power and an “L” in the box of the trial that they think will produce the largest power. If they think that all trials will produce the same power, they will write “same” over all boxes. Have students get into their groups and start designing their experiment.

Place the class example question under the document camera so that students can refer back to it as they design their experiment. As subgroups move onto their experimental set-up, put the example experimental set-up under the document camera.

**Question:**
*(9 minutes – Subgroups – SciTrek Volunteers)*

Have subgroups decide what changing variable(s) they want to explore for their first experiment. If they only have one changing variable, do not encourage them to have more, or if they have two changing variables, do not encourage them to have fewer. Students will analyze their data and then perform an additional experiment to correct any mistakes that they made on their first experiment.

Each subgroup should briefly discuss how/why they think their changing variable(s) will affect the power produced by the solar panel.

After subgroups have decided on their changing variable(s), have them fill out their question. When you sign off on their question, give them an experiment 1 materials page with their subgroup color and number designated in the upper right-hand corner. An example of a filled out question is shown below.
Materials Page:
(7 minutes – Subgroups – SciTrek Volunteers)

Have subgroups underline their control(s) and circle their changing variable(s) on the experiment 1 materials page. Then have them use the experiment 1 materials page to determine the values for their changing variable(s) and control(s). For the changing variable(s) values, have students write the trial letter under the value they select. Ask students, “Why did you choose the values for your changing variable(s) and control(s) and will these values make it easier or harder to answer your question?”

Make sure students have picked panel angles, shading amounts, and temperatures that are within the limitations given on the experiment 1 materials page. An example filled out experiment 1 materials page is shown in the Experimental Set-Up section.

Experimental Set-Up:
(8 minutes – Subgroups – SciTrek Volunteers)

Have subgroups use their experiment 1 materials page to fill in their experimental set-ups on page 6 of their notebooks. For subgroups that have two changing variables, there will be one control blank that will not come from the materials page, students should put light source/lamp. When you sign off on their experimental set-up, collect the experiment 1 materials page and verify that it is filled out correctly and completely. Having the experiment 1 materials page filled out is essential for students to start their experiments during the next SciTrek visit. An example filled out experimental set-up is shown below (right).
Procedure:
(18 minutes – Subgroups – SciTrek Volunteers)

After each subgroup has filled out their experimental set-up, they can start on their procedure (page 7, student notebook). Make sure that students within the same subgroup are collaborating to write the procedure. Keep procedures as brief as possible while still conveying the pertinent information about the experiment (control values, changing variable values, and what data they will collect). An example step for a subgroup that had panel angle as a changing variable would be: “Place the panel at an angle of A) 30°, B) 45°, C) 60°, and D) 75°.” Some subgroups may struggle with writing a procedure. You can have these subgroups dictate each step while you transcribe them onto a notepad found in your group box. Give this sheet to the students to copy into their notebooks. Once the students have finished, they should raise their hand and get their procedure approved by their volunteer. An example procedure can be seen below (left).

Note: Students in each subgroup can vary the wording in their procedures as long as the steps are in the same order and the correct values are included. 6th grade students are more independent and capable of writing procedures on their own, so as long as the necessary information (all control and changing variable values and data collection) is included, the wording does not have to exactly match.

Tell students that they will now fill out the results table.
**Results Table:**  
(3 minutes – Subgroups – SciTrek Volunteers)

Have students underline the variables that are controls, circle the variables that are their changing variable(s), and box the data collection. When writing the values, make sure that for controls, they only write the value of the control in the “trial A” box and then draw an arrow through the remaining trials; for the changing variable(s), they write the value in each of the boxes.

When students have finished, have them make predictions about the power produced by the solar panel. Have them write an “L” in the box of the trial they think will give the largest power output and an “S” in the box of the trial they think will give the smallest power output. They will leave two of the boxes empty. If they think all trials will give the same power output, have them write “same” over all of the boxes. See example notebook in Procedure section).

**Wrap-Up:**  
(3 minutes – Full Class – SciTrek Lead)

If there is time, have one student from each subgroup share what question they will investigate. Tell students that during next session they will start their experiments. Tell students that all of their experiments will help us answer the class question: what variables affect the amount of power produced by the solar panel?

**Clean-Up:**

Before you leave, have students attach their nametag to their notebook and place them in the group box. Place the materials pages on top of the notebooks in your group box. Bring all materials back to UCSB. In addition, put your lab coat into your group box.
Day 3: Experiment/Analysis Activity/Conclusion

Schedule:

- Introduction (SciTrek Lead) – 7 minutes
- Experiment (SciTrek Volunteers) – 20 minutes
- Analysis Activity (SciTrek Lead) – 26 minutes
- Conclusion (SciTrek Volunteers) – 6 minutes
- Wrap-Up (SciTrek Lead) – 1 minute

Materials:

(3) Volunteer Boxes:
- ☐ Student nametags
- ☐ Student notebooks
- ☐ Volunteer instructions
- ☐ (2) Pencils
- ☐ Solar panel holders

(3) Ziploc bags with the following: (labeled with subgroup number)
- ☐ Protractor
- ☐ Solar panel
- ☐ Multimeter
- ☐ IR thermometer
- ☐ Spacing tool
- ☐ Shading tool
- ☐ (2) Binder clips
- ☐ Protractor
- ☐ Filled out experiment 1 materials page

Other Supplies:
- ☐ (2) Boxes of lamps with 6 extension cords
- ☐ Calculator box
- ☐ Box with 10 hair dryers

Lead Box:
- ☐ (3) Extra student notebooks
- ☐ Lead instructions
- ☐ Solar Power picture packet
- ☐ Lead lab coat
- ☐ Time card
- ☐ (2) Pencils
- ☐ (2) Red pens
- ☐ (2) Wet erase markers
- ☐ Solar panel holder
- ☐ IR thermometer
- ☐ Spacing tool
- ☐ Shading tool
- ☐ (2) Multimeters
- ☐ (2) Binder clips
### RESULTS Table

Fill in the chart for each of your trials. For the variables that remain constant, write the value in trial A. Then draw an arrow through each box indicating that this variable is a control. Remember to record data measurements to the nearest tenth (Ex: 6.1 mA). Calculate power to the nearest tenth (Ex: 13.1 W).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Trial A</th>
<th>Trial B</th>
<th>Trial C</th>
<th>Trial D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Source</td>
<td>Solar panel</td>
<td>30°</td>
<td>90°</td>
<td>150°</td>
</tr>
<tr>
<td>Panel Angle</td>
<td>15°</td>
<td>30°</td>
<td>45°</td>
<td>60°</td>
</tr>
<tr>
<td>Shading Amount</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>Temperature</td>
<td>22°C</td>
<td>22°C</td>
<td>22°C</td>
<td>22°C</td>
</tr>
<tr>
<td>Light Source</td>
<td>Lamp</td>
<td>Lamp</td>
<td>Lamp</td>
<td>Lamp</td>
</tr>
<tr>
<td>Predictions</td>
<td>Trial A</td>
<td>Trial B</td>
<td>Trial C</td>
<td>Trial D</td>
</tr>
<tr>
<td>Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room Temperature</td>
<td>22°C</td>
<td>22°C</td>
<td>22°C</td>
<td>22°C</td>
</tr>
<tr>
<td>Current (mA)</td>
<td>1.7mA</td>
<td>0.7mA</td>
<td>5.3mA</td>
<td>3.8mA</td>
</tr>
<tr>
<td>Voltage (V)</td>
<td>2.0V</td>
<td>1.0V</td>
<td>2.0V</td>
<td>1.0V</td>
</tr>
<tr>
<td>Power (W)</td>
<td>3.4W</td>
<td>0.7W</td>
<td>10.6W</td>
<td>3.8W</td>
</tr>
<tr>
<td>P = 5 x 10^4 J</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The independent variable(s) are the changing variables and the dependent variables are the current, voltage, and power.

### SCIENTIFIC PRACTICES

#### Analysing & Interpreting Data

1. Directions: Fill in the missing definitions.
   - Conclusion: A claim supported by data
   - Claim: A statement that can be tested. The explanation of the data, the first part of a conclusion.
   - Example: Increased amount of fertilizer runoff in lakes kills wildlife.
   - A claim in a scientific experiment often includes the changing variable.
   - Data: Evidence collected from experiments (measurements or observations), the second part of a conclusion.
   - Example: We observed that in lakes with large amount of fertilizer runoff, there were many dying fish and plants. In lakes with small amount of fertilizer runoff, there were many healthy fish and plants.
   - The data in a scientific experiment includes measurement or observation.
   - Data statements also often include values of the changing variable.

2. Directions: On the results tables and conclusions below, under each question, circle each changing variable. Circle each box containing information on data collection. Then, decide if the possible conclusion is correct or not.

   a) Variables: Trial 1 | Trial 2 | Trial 3 | Trial 4
   - Power Plant Type: Solar | Solar | Solar | Solar
   - Substitution Amount: 1000 Mg | 1500 Mg | 2000 Mg | 2500 Mg
   - Number of Generators: 3 | 5 | 7 | 9
   - Total Measurement: 48 h | 60 h | 72 h | 84 h
   - Final Measurements: Other | Other | Other | Other
   - Air around plant is clear | Air around plant is clear | Air around plant is clear | Air around plant is clear
   - Possible Conclusion: Having more generators in the power plant will produce more power, because when more people were working, more power was produced, and when less people were working, less power was produced.
   - Is this a correct conclusion? YES | NO | I DON'T KNOW
   - If NO, what is wrong with the conclusion? Incomplete claim.

3. How many changing variables can you have to make a conclusion?
**Preparation:**

**SciTrek Lead:**
If the classroom has a document camera, ask the teacher to use it for the introduction (page 1, picture packet) and the Analysis Activity (pages 9-11, student notebook). If the classroom does not have a document camera, then tape example poster-size notebook pages to the front board.

Have a solar panel, solar panel holder, spacing tool, shading tool, multimeter, thermometer, hair dryer, and lamp available to show students during the introduction.

**SciTrek Volunteers:**
Set out student notebooks.
- If students are not in the classroom before SciTrek starts, set out the notebooks where students should sit when they come into the classroom.
- If students are in the classroom before SciTrek starts, set out the notebooks where students should sit during the module; they will move to these spots after the introduction.

Plug in extension cords and lamps and place them at each spot your subgroups will work at so they are ready to start their experiment promptly after finishing their results table.

Have all supplies separated and ready so that you can set them out as soon as your subgroups are ready to start.
If needed, while you are doing the introduction have volunteers set out the notebooks/nametags where they would like students to sit. Make sure that students in the same subgroup are sitting next to each other. Tell students that a notebook will be put on their desk, which is not their notebook and they should not move it.

Ask the class, “What is the class question that we are investigating?” The students should reply, “What variables affect the power produced by a solar panel?” Ask students, “What is power and how do we calculate it?” Possible student response: power is the energy per time and is calculated by multiplying the current and voltage. Ask students, “What units will we measure current and voltage?” Possible student response: volts (V) and milliamps (mA). Ask students, “What units will power be in?” Possible student response: milliwatts (mW).

Tell students that today they will do their experiment to answer the class question. However, before they can start their experiment, they need to have their results tables completed (students should have completed this the previous SciTrek visit). Once this is finished, they can raise their hands and they will receive their experimental supplies from their volunteer.

Place a set of experimental supplies under the document camera (solar panel, solar panel holder, spacing tool, shading tool, multimeter, thermometer, hair dryer, and lamp). Tell students, “I will remind you how to set up the solar panel and demonstrate how to collect the data for this experiment.” Connect a multimeter to the solar panel set up while reminding the students that they need to connect the wires of the multimeter and the solar panel by the same color (red wire to red wire and black wire to black wire). Next, tell students that if they are shading their solar panel, the shading amount increases from the bottom of the solar panel to the top of the solar panel. Demonstrate on the example solar panel where $\frac{1}{8}$ shading and $\frac{7}{8}$ shading would be.

Place the solar panel into the holder. Show students how to insert the spacing tool between the lamp and the panel (while the panel is at 90°) to set the correct light distance. Tell students that now that their lamp is at the correct placement they can remove the solar panel to set the angle of the panel. Ask students, “What tool should we use to help us measure the angle of our panel?” Pull out the protractor and show students where to place it on the solar panel holder. Remind them that when measuring the angle of the panel, they will use the colored scale on the protractor. Turn the picture packet to page 1 and place it under the document camera. Tell students that for this experiment the scientist were trying to have the angle at 45°. Tell students they while looking directly at the protractor they will move the solar panel until the angle of the solar panel matches the angle of the swing arm. They can then put the solar panel directly under the lamp without changing the lamp height.
Tell students that when they record their data, they will make three measurements: the room temperature, the current, and the voltage. Show students where they will record these three things on the results table (page 8, student notebook). They should use the thermometer to take the temperature of the room before starting their experimental trials. On the example solar panel set up under the document camera, point to the silver dot in the middle of the solar panel. Tell students first they need to hold the thermometer 90° from the panel. They should then point the thermometer at the silver dot in the center of the solar panel when taking the temperature, just like you are demonstrating now. If their panel is shaded more than $\frac{4}{8}$, they will need to point their thermometer at the correct dot, as indicated on the shading tool. Place the shading tool on the solar panel at $\frac{7}{8}$ shaded and demonstrate how to take the temperature at the correct dot. An example picture is shown below.

If they are heating their solar panel, tell students that they will break up their group so each of them has a role. One student will operate the thermometer and hairdryer, one student will read the current and voltage on the multimeter, and another student will record the values in their notebook. Tell students that they should rotate roles between trials. (Note: If there are more than 3 students, extra students will observe for the trial but then rotate into a position for the next trial) Tell the students, “The person
reading the multimeter should start with their multimeter on to the black boxed setting to record the current first. When the person operating the thermometer tells you they are ready, you should call out the current and immediately twist the dial to the silver boxed setting to call out the voltage.” Show the students under the document camera how to flip between the current and voltage settings.

Next, tell the students, “The person operating the thermometer should hold the thermometer about 6 inches from the panel at a 90° angle and take the initial temperature. Then, pull the thermometer away and begin to heat the solar panel for “10 s making sure to sweep the hair dryer back and forth across the solar panel. Take the temperature again and make sure you are at least 2° above your goal temperature. If the temperature is at least 2° above your goal temperature, stop the hair dryer and allow the panel to cool until you reach your goal temperature. Signal your subgroup partner reading the multimeter to call out the current and voltage.” (Note: You do not need to turn on the hair dryer for this demonstration, just show the students the motion.)

Tell students that once they have completed their trials, they should calculate the power produced by each solar panel (to the nearest tenth).

**Experiment:**

*(20 minutes – Subgroups – SciTrek Volunteers)*

Once you have verified that subgroups have finished their results table, give them their requested materials. If students are missing any of their experimental materials, the lead box has extra materials. Have your subgroups show you their first set up so you can approve it before moving on. Verify they have the correct angle of their solar panel by using the colored scale of the protractor to determine the angle. If you have a group using a temperature other than room temperature, stay to observe their first trial to make sure it runs smoothly. Make sure the students have assigned themselves roles and know to rotate between trials. One student should run the hair dryer and thermometer, one student should call out the multimeter measurements (and flip between the current and voltage), and one student should write down the measurements. Remind subgroups that they will read the current from the setting boxed in black and the voltage from the setting boxed in silver on the multimeter.

Students should record the current and voltage during each trial, but have students wait until they have finished the entire experiment to calculate the power output for each trial. Allow the students to keep their materials on their desks while they are working on calculating the power. If there is extra time, they may repeat any trials to check their results. If your group has things under control, help other subgroups. An example of a properly filled out results table is shown below.
While the lead starts on the Analysis Activity, have volunteers clean up. All materials should be returned to the group boxes, except the lamps and calculators.

**Analysis Activity:**
(26 minutes – Full Class – SciTrek Lead)

Tell the students to turn to page 9 in their notebooks while you turn to page 9 in the class notebook under the document camera. Mention that before they analyze their results and draw a conclusion, it is important that they recognize and understand other scientists’ conclusions.

Ask the class, “What is a conclusion?” After listening to the students’ answers, make sure that the students understand that a conclusion is a **claim supported by data**. Write this definition on page 9 of the class notebook for the students to copy.

Tell the students that in order to make a conclusion we need to make sure that we understand the difference between a claim and data. Read the definition of a claim (A statement that can be tested. The explanation of the data, the first part of a conclusion).

Then read the example, “Increased amounts of fertilizer runoff in lakes kills wildlife.” Ask someone in the class to propose how you would test this claim. Possible student response: find lakes with different amounts of fertilizer being poured into them and observe the amount of life in the lake.” Then, ask someone else if they can identify what the changing variable would be in that experiment. Lead students to notice that the changing variable (fertilizer runoff amount) was included in the claim, and circle amounts of fertilizer runoff in the example. Read the sentence frame to students, “A claim in a scientific experiment often includes the ________.” Ask students, “What should we write in the blank?” They should reply, “changing variable.”
Next, read the definition of data (Evidence collected from experiments(s) (measurements or observations), the second part of a conclusion). Then read the example, “we observed that in lakes with large amounts of fertilizer runoff, there were no living organisms while in lakes with a little fertilizer runoff, there were many living organisms.” Note that the example data supports the example claim, therefore, a conclusion can be formed by combining the two statements. This conclusion would be: Increased amounts of fertilizer runoff in lakes kills wildlife, because we observed that in lakes with large amounts of fertilizer runoff, there were no living organisms while in lakes with a little fertilizer runoff, there were many living organisms. Tell students that there are two forms of data collection, measurements and observations. If measurements were collected for data, then numerical values should be in the data statement. If observations were collected for data, then words such as observed or recorded should be in the data statement to allow you to know that an experiment was performed. Read the first sentence frame to students, “Data in a scientific experiment includes ___________ or ___________. “ Ask students, “What should we write in the blanks?” They should reply, “Measurements and observations.” Ask students, “In our example data statement, what was the method of data collection and how do you know?” Possible student response: the method of data collection was observations because the words “we observed” are in the statement. Ask students, “What data were these scientists observing?” Possible student response: the scientists were observing the amount of living organisms in the lakes, specifically there were no living organisms and many living organisms. Ask students, “What changed between the two lakes that caused them to have different amounts of living organisms?” Possible student response: the lakes had different amounts of fertilizer runoff. Lead students to understand that large amounts and a little are values of the changing variable. Have the students circle the values of the changing variable and box the observations in the data statement. Read the second sentence frame to students. “Data statements also often include values of the ___________. “ Ask students, “What should we write in the blank?” They should reply, “Changing variable.”

Read the directions to part 2 aloud to the class (On the results tables and conclusions below, underline control(s), circle changing variable(s), and box information about data collection. Then, decide if the possible conclusion is correct or not.) Call on individual students to tell you how each item in the results table should be annotated. Then, read the full conclusion to the students. Have students tell you if there is anything that should be underlined, circled, or boxed and annotate the conclusion appropriately.

For annotating, do parts a and b as a class, and then take the notebook off the document camera and have students try to do parts c, d, and e on their own, while you fill them out off to the side. While students are working, have volunteers walk around and help them if needed. Then, put the notebook back under the document camera for them to check their work.

Use the following question flow chart for each conclusion to help students understand if the conclusion is correct or not:

What type of statement is before the “because” and how do you know?
  If the statement is data (contains a measurement or observation)
    o What type of statement is after the “because” and how do you know? (claim because it can be tested)
    o Can this be a correct conclusion? (No)
    o What is wrong with the conclusion? (claim and data switched)
    o Move onto next conclusion
If the statement is a claim (can be tested)
- What is the changing variable in this claim?
- Is this a changing variable in this experiment? (Yes)
- Is the claim consistent with the results table?

If No
- Can this be a correct conclusion? (No)
- What is wrong with the conclusion? (incorrect claim)
- Move onto next conclusion

If Yes and 1 changing variable
- What type of statement is after the “because” and how do you know? (Data because it contains a measurement or an observation)
- Is the data consistent with the results table? (Yes)
- Is this a correct conclusion? (Yes)
- Move onto next conclusion.

If Yes and 2 changing variables
- What type of statement is after the “because” and how do you know? (Data because it contains a measurement or an observation)
- Is the data consistent with the results table? (Yes)
- Is this a fair conclusion? (No because the change could be due to the other changing variable.)
- Is this a correct conclusion? (No)
- What is wrong with the conclusion? (more than 1 changing variable)
Below are the explanations and answers to part 2 letters a-e on pages 9, 10, and 11.

**Letter a:**

*Table Annotations:*
- Underline: Power Plant Type, Substance Amount, Water Amount, Number of Workers
- Circle: Number of Generators
- Box: Power Output, Other

*Conclusion Annotations:*

The greater the number of generators in the power plant the higher the power output, because when 2 generators were used, 103 MW of power were produced, and when 5 generators were used, 150 MW of power were produced.

*What type of statement is before the “because” and how do you know?*
- Claim because it can be tested

*What is the changing variable in the claim?*
- Number of generators

*Is this a changing variable in this experiment?*
- Yes

*Is the claim consistent with the results table? (check table with students)*
- Yes

*What type of statement is after the “because” and how do you know?*
- Data because it contains measurements

*Is the data consistent with the results table? (check table with students)*
- Yes

*Is this a correct conclusion?*
- Yes
Letter b:

Table Annotations:
- Underline: Power Plant Type, Substance Amount, Number of Generators, Water Amount
- Circle: Number of Workers
- Box: Power Output, Other

Conclusion Annotations:
- Having more people working the power plant will produce more power, because when 8 people were working, 140 MW of power were produced, and when 14 people were working, 141 MW of power were produced.
- *Note:* Circle “people working” and write “# of workers” above to make the changing variable more clear.

What type of statement is before the “because” and how do you know?
- Claim because it can be tested

What is the changing variable in the claim?
- Number of workers

Is this a changing variable in this experiment?
- Yes

Is the claim consistent with the results table? (check table with students)
- Yes

What is wrong with the conclusion?
- Incorrect claim

Letter c:

Table Annotations:
- Underline: Power Plant Type, Number of Generators, Water Amount, Number of Workers
- Circle: Substance Amount
- Box: Power Output, Other

Conclusion Annotations:
- As more coal is burned in the power plant the air will become more polluted, because we observed when 2,700 Mg of coal were burned, the air was light brown, and when 4,299 Mg of coal were burned, the air was dark brown.
- *Note:* Circle “more coal” and write “substance amount” above, because “more coal” really refers to the amount of coal, which in this case is referred to as substance amount in the results table.

What type of statement is before the “because” and how do you know?
- Claim because it can be tested.

What is the changing variable in the claim?
- Substance amount

Is this a changing variable in this experiment?
- Yes

Is the claim consistent with the results table? (check table with students)
- Yes

What type of statement is after the “because” and how do you know?
- Data because it contains observations.

Is the data consistent with the results table? (check table with students)
- Yes

Is this a correct conclusion?
- Yes
Letter d:

**Table Annotations:**
- Underline: Power Plant Type, Substance Amount, Number of Generators, Number of Workers
- Circle: Water Amount
- Box: Power Output, Other

**Conclusion Annotations:**
- When 4,200 L of water were used, $155 \text{ MW}$ of power were produced, and when 4,800 L of water were used, $128 \text{ MW}$ of power were produced, because the greater the amount of water the lower the power output.

**What type of statement is before the “because” and how do you know?**
- Data because it contains measurements.

**What type of statement is after the “because” and how do you know?**
- Claim because it can be tested.

**Is this a correct conclusion?**
- No

**What is wrong with the conclusion?**
- Claim and data are switched.

Letter e:

**Table Annotations:**
- Underline: Power Plant Type, Number of Generators, Number of Workers
- Circle: Substance Amount, Water Amount
- Box: Power Output, Other

**Conclusion Annotations:**
- The greater the amount of water used in the power plant the higher the power output, because when 4,000 L of water were used, $130 \text{ MW}$ of power were produced, and when 4,700 L of water were used, $155 \text{ MW}$ of power were produced.

**What type of statement is before the “because” and how do you know?**
- Claim because it can be tested.

**What is the changing variable in the claim?**
- Water amount

**Is this a changing variable in this experiment?**
- Yes

**Is the claim consistent with the results table? (check table with students)**
- Yes

**What type of statement is after the “because” and how do you know?**
- Data because it contains measurements.

**Is the data consistent with the results table? (check table with students)**
- Yes

**Is this a fair conclusion?**
- No, there are multiple changing variables therefore, it could be the substance amount that is changing the amount of power produced and not the water amount.

**Is this a correct conclusion?**
- No

**What is wrong with the conclusion?**
- More than 1 changing variable.

Ask students, “When designing an experiment, how many changing variables can you have in order to make a conclusion from your data?” Students should tell you only 1. Record this for number 3 on the bottom of page 11.
Inform students that they are now going to analyze their own data from their first experiment to see if they can draw a conclusion.

**Conclusion:**

*(6 minutes – Subgroups – SciTrek Volunteers)*

Help subgroups fill out page 12 of their notebook. If the subgroup has more than one changing variable, they will not be able to draw a conclusion. An example of when the students cannot make a conclusion is shown below on the left.

If the subgroup has only one changing variable, they will be able to make a conclusion.

When writing their conclusion, make sure students start the statement with a claim (statement that can be tested) about the trend or pattern in their data. If the values of their changing variable have an order (Ex: $80^\circ \rightarrow 65^\circ \rightarrow 45^\circ \rightarrow 30^\circ$), then that variable affects the power produced by the solar panel. If, on the other hand, there was no order for their changing variable values (Ex: $30^\circ \mathrm{C} \rightarrow 26^\circ \mathrm{C} \rightarrow 44^\circ \mathrm{C} \rightarrow 35^\circ \mathrm{C}$) and the difference between the power outputs for each trial is small, then that variable did not affect the power produced by the solar panel. Since this is an engineering activity, students’ claims should be focused on the value (or pattern of values) of their changing variable that produced the most power and allows them to make a prediction. An appropriate claim could be: the less shading on the solar panel the more power is produced. This is an appropriate claim because it allows the students to make a prediction about what would happen if new values of their changing variable were introduced and identifies which value would produce the most power.

After generating a claim about the experiment, students will put their supporting data after the “because” to back up their claim. Their supporting data should include at least two pieces of data. Make sure students are using their changing variable values (not trial letters) and specific measurements to support their claim. The supporting data for the previously mentioned claim would be: when the panel was $\frac{8}{8}$ shaded the power produced was 0 mW and when the panel was $\frac{0}{8}$ shaded the power produced was 4.8 mW. The supporting data should be the two most convincing data points, typically the minimum and maximum power produced.

Conclusions are still valid and important, if they show that the changing variable tested did not affect the power output. Even if their conclusion is contrary to what you think, have students make a claim based solely on their data. If you think that their data is flawed, it is okay to ask them what they think went wrong and encourage them to repeat their experiment. An example of when the students can make a conclusion is shown below on the right.
Wrap-Up:
(1 minute – Full Class – SciTrek Lead)

Tell students that during the next session they will then discuss their findings as a class to determine how they can make changes to their experiments to better answer the class question. After, they will work on developing techniques to help them analyze their data.

Clean-Up:

Before you leave, have students attach their nametag to their notebook and place them in the group box. Make sure that all of the calculators have the covers on and are placed back into the calculator box and the lamps, extension cords, and hair dryers are back in their boxes. Bring all materials back to UCSB. In addition, put your lab coat into your group box.

Day 4: Technique 1/Technique 2/Analysis Activity

Schedule:

Introduction (SciTrek Lead) – 3 minutes
Findings Discussion (SciTrek Lead) – 10 minutes
Technique (Percentages) (SciTrek Lead) – 10 minutes
Technique (Trend Lines/Designing Experiments) (SciTrek Lead) – 15 minutes
Analysis Activity (SciTrek Lead) – 20 minutes
Wrap-Up (SciTrek Lead) – 2 minutes
Materials:

(3) Volunteer Boxes:
- ☐ Student nametags
- ☐ Student notebooks
- ☐ Volunteer instructions
- ☐ Volunteer lab coat
- ☐ (2) Pencils
- ☐ (12) Clear rulers
- ☐ (2) Red pens

Other Supplies:
- ☐ Calculator Box

Lead Box:
- ☐ (3) Extra student notebooks
- ☐ Lead lab coat
- ☐ Time card
- ☐ (2) Pencils
- ☐ (2) Red pens
- ☐ (2) Wet erase markers
- ☐ (5) Clear rulers

Notebook Pages and Picture Packet Page:

**TECHNIQUE**

**Calculating Percentages**

Percentages are used to compare a portion of a system to a whole system. This is done by making the amount of the whole system equal to 100. The closer the value is to 100, the larger the portion of the system.

**How to Calculate Percentages**

Step 1. Define your system:
- a. Determine the number you want to change into a percent (value).
- b. Determine the smallest number in your system (minimum).
- c. Determine the largest number in your system (maximum).

**Equation 1:**

\[ \text{Percent} = \left( \frac{\text{value} - \text{minimum}}{\text{maximum} - \text{minimum}} \right) \times 100 \]

**Directions:** Find the percent for each of the following values in the table.

<table>
<thead>
<tr>
<th>(a) Panel Angle: 5°</th>
<th>(b) Shadow Amount: 21.2°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowed values for each variable.</td>
<td>21.2°</td>
</tr>
<tr>
<td>Step 1: Panel Angle (5° - 90°)</td>
<td>21.2°</td>
</tr>
<tr>
<td>Step 2: Range</td>
<td>0.0 - 0.9</td>
</tr>
<tr>
<td>Step 3: Calculations</td>
<td>0.0 - 0.9</td>
</tr>
</tbody>
</table>

**Other Supplies:**
- ☐ Calculator Box

**TECHNIQUE**

**Trend Lines**

Trend lines are used to find trends in data on graphs.

**Directions:**

1. Put your ruler on the graph so it goes along with the direction of the points and places half the points above the ruler and half the points below it.
2. Make sure all points are as close as possible to the ruler, and then trace along the ruler with your pencil. Always extend trend lines to both edges of the graph.

**Graph 1:**

- Effects of Pressure Change on Power Output

**Graph 2:**

- Objects' Average Change of Weight vs. Number of Workers

**Graph 3:**

- The Points are No Closer together.

**Directions:**

1. Which graph(s) represent a changing variable that affects the data?
2. Which changing variable affects the data?
3. Describe the trend by filling in the following sentence frame:
   As the percentage of **variable** increases, the power output **increases**.

**Notebook Pages and Picture Packet Page:**
Preparation:

SciTrek Lead:
If the classroom has a document camera, ask the teacher to use it for the Findings Discussion (page 2, picture packet), technique activities (pages 13-15, student notebook), and Analysis.
Activity (pages 16-17, student notebook). If the classroom does not have a document camera, then tape example poster-size notebook pages to the front board.

SciTrek Volunteers:
Set out student notebooks.
- If students are not in the classroom before SciTrek starts, set out the notebooks where students should sit when they come into the classroom.
- If students are in the classroom before SciTrek starts, set out the notebooks where students should sit during the module; they will move to these spots after the introduction.

Introduction:
(3 minutes – Full Class – SciTrek Lead)

If needed, while you are doing the introductions have volunteers set out the notebooks/nametags where they would like students to sit. They will move into their subgroups after the introduction.

Ask students, “What did you do during the last meeting with SciTrek?” Possible student response: we conducted experiments to answer the class question, “What variables affect the power produced by a solar panel?” We then looked at conclusions to determine if they were appropriate for a given set of data. Then we analyzed our own data to determine if we could make a conclusion. If we had only one changing variable, then we made conclusions from our data.

Briefly review what we learned about conclusions last time.

What is a conclusion?
A claim supported data

What is a claim, and what does it usually include?
A statement that can be verified by testing, which may include the changing variable

What type of information can be used for data?
Measurements or observations

What else do we often see in a data statement?
Values of the changing variable

Can the claim and the data statements be in any order for the conclusion?
No, the claim must come first, followed by the data that supports it

How many changing variables can we have to make a conclusion and why?
One, if we test more than one changing variable at the same time, there is no way of telling which variable affected the data

Findings Discussion:
(10 minutes – Full Class – SciTrek Lead)

Tell students, “Last time we worked in our subgroups to write a conclusion, if our data allowed. Today we will discuss our results as a class.”

If necessary, have students move into their subgroups.

Place page 2 of the picture packet under the document camera. First ask students, “Who could not make a conclusion?” For any subgroups that raise their hands, ask them “Why couldn’t you make a conclusion?” They should reply, “We had more than one changing variable.” Ask those subgroups, “What would you do differently in order to be able to make a conclusion next time?” They should reply, “We will only choose
one changing variable in our next experiment.” Record this on the class findings list under “Experimental Design” (page 2, picture packet).

Next, go through each variable (panel angle, shading amount, temperature), and ask students to raise their hand if this was their changing variable. Have those subgroups read their conclusion. If multiple subgroups had the same changing variable, ask them if their results are in agreement. Record brief summaries for each variable that was tested on the class findings list under “Conclusion Summaries.” Record all findings about one changing variable before moving onto findings about other changing variables. If subgroups have conflicting conclusions about the same changing variable, record both and remind the students that we will be conducting more experiments to find out how the changing variable affects the power output. An example filled out class findings page is shown below. (Note: there may be only a few, or even zero, groups that are able to make conclusions at this point, so you may not be able to record many findings. However, the example below shows conclusion summaries for all possible changing variables.)

Technique (Percentages):
(10 minutes – Full Class – SciTrek Lead)

Have the volunteers pass out a calculator to each student.

Tell the class, “We are now going to work on a technique that will be useful in comparing the data in our next experiments.” Ask the class, “What were the units we used when measuring the panel angle?” They should reply, “Degrees.” Repeat the question for shading amount (fraction) and temperature (degrees Celsius). Tell students, “In order to be able to graph our results, we must all be using the same scale to accurately compare how each of the variables affect the power produced by the solar panel. Since each of the variables uses different units, we can solve this problem by graphing in percentages.”
Have students turn to page 13 in their notebook while you turn the class notebook to page 13 under the document camera. Read the paragraph at the top of page 13 to students. “Percentages are used to compare a portion of a system to a whole system. This is done by making the amount of the whole system equal to 100%. The closer the value is to 100%, the larger the portion of the system.”

Tell students, “To find the percentage you will use three steps.” Direct student attention to Step 1 (define your system) and read it to them (a. determine the number you want to changing into a percent (value) b. determine the smallest number in your system (min value) c. determine the largest number in your system (max value)). Have students look at number 1. Tell students, “The system refers to the variable we are working with in the problem.” Ask students, “What variable are we working with in number 1?” Students should reply, “Panel angle.” Ask students, “What value do we want to change into a percent?” Student should reply, “50°.” Direct students’ attention to the “allowed values for each variable” section of the table. Ask students, “What is the minimum value in our system?” Students should reply, “30°.” Ask students, “What is the maximum value in our system?” Students should reply, “90°.”

Read Step 2 to students (calculate the range using Eq. 1. The range is equal to the difference between the largest and smallest accepted values in your system). Point to Equation 1 on the page and tell students we need to subtract our min value from our max value. Have students write the max value in the first blank and the min value in the second blank. Ask students, “What is 90° - 30° equal to?” Then write the answer, 60°, in the third blank.

Tell students, “Now that we’ve found our range, we can move on to Step 3.” Read Step 3 to students (use Eq. 2 to calculate the percentage and round to the nearest whole number. Percentages are unit less.) Point to Equation 2 on the page and tell students we need to fill in the equation frame in number 1 with our values. Tell students that because percentages are unit less, we will not write the units on the numbers that we plug into the equation. (Note: 6th grade does not cover unit cancellation, so forgoing the units in the percentage equation is workaround to teaching unit cancellation.) Ask students, “What is our value?” Write 50 in the appropriate blank in the equation frame. Ask students, “What is the minimum value?” Write 30 in the appropriate blank in the equation frame. Ask students, “What is the range?” Write 60 in the bottom blank in the equation frame.

Place a calculator under the document camera and turn it on. Show the students how to input the equation into the calculator. A picture of the screen is shown below. (Note: in order to create the fraction, you must press the \( \frac{\text{num}}{\text{den}} \) button on the calculator.

Press the “enter” button on the calculator. The calculator will produce an improper fraction as the answer. Tell students, “To convert this to a decimal, we will press the “\( \rightarrow \)” button on the calculator.” Your screen will now show a repeating decimal (33.33). Tell students, “We need to round this number to the nearest whole number.” They should round to 33%. Record this answer for number 1. Repeat this
process for number 2, then have students try numbers 3 and 4 on their own. Have the volunteers walk around to help struggling students.

Once students have completed numbers 3 and 4, check the answers as a class. An example filled out page 13 is shown below.

Technique (Trend Lines):
(15 minutes – Full Class – SciTrek Lead)

Tell the class they are now going to work on techniques to help them analyze their data so that they will be able to design new, “better” experiments during the next SciTrek visit. Have volunteers collect the calculators and pass out a clear ruler to each student to use during the technique and analysis activities. Keep the picture packet close by, as you will need to record two more class findings during this Technique Activity.
Tell students, “We are going to learn about trends. Trends are when data changes in one general direction, either going up or going down. If the data points all line in a flat line, then there is no trend in the data. We are going to use trend lines to help us recognize trends in data.” Open a class notebook to page 14 under the document camera, and have the students turn to page 14 of their notebooks.

First, tell students that we are going to look at a graph of data collected from a natural gas power plant. Have students look at Graph 1. Tell students that the changing variable is always found on the x-axis (horizontal), then ask students, “What the changing variable is in Graph 1?” They should reply, “Percent natural gas amount.” Then have them circle it. Tell students that the data collected is found on the y-axis (vertical), then ask students, “What data was collected?” They should reply, “Power output in MW.” Then have them box it. Have students remind you what the units are for the power in our experiment (milliwatts) and how we wrote them (lowercase m, capital W). Tell students that the units for power in these graphs are capital M, capital W. This is read as megawatts. Ask students, “Do you see the changing variable or the data anywhere else on the graph?” They should reply, “The title.” Ask students, “What should we do to the title?” They should reply, “Circle Percentage of Natural Gas and box Power Output.” Repeat this process for Graph 2. Make sure students annotate the graphs in their notebooks along with you.

Read the directions for how to draw a trend line (1. Put your ruler on the graph so it goes along with the direction of the points and places half the points above the ruler and half the points below it. 2. Make sure all points are as close as possible to the ruler, and then trace along the ruler with your pencil. Always extend trend lines to both edges of the graph,) and then use a clear ruler to show students how to draw a trend line on Graph 1. Repeat the process for Graph 2. Read how to interpret trend lines to students (If the line is increasing (\) or decreasing (\) there is a trend. If the line is flat (—) there is no trend) and have them draw in the appropriate lines. (Note: Use the word “flat” rather than “straight” when describing trend lines that show no trend, because all lines are straight.) Explain to students that when a graph shows a trend, the changing variable affects the data, and when a graph does not show a trend, the changing variable does not affect the data.

Go over question 2 as a class. Ask students, “Does either of the graphs have a trend?” They should respond, “Graph 1 has a trend, but Graph 2 does not.” Therefore, only changing the percentage of natural gas will affect the data. Then, ask students, “What happens to the power output when the percentage of natural gas increases?” Possible student response: as the percentage of natural gas increases the power output increases. Have the students fill this into the sentence frame in question 2b.

For question 3, annotate the graph as a class. Then tell students that you will draw a trend line onto the data. Put the ruler on the paper in the three ways shown in the pictures below. Ask students, “Which placement is correct?” Lead students to understand that it is impossible to tell which way is correct because the data points are too close together. Finally, ask students, “What does this mean for your experiment?” Possible student response: we need to pick values for our changing variable that are spread out/not similar. Add this point to the Findings under “Experimental Design” (page 1, picture packet) and fill in question 3. An example filled out page 14 is shown below.
Tell students we will now work on developing techniques to help design experiments as a class. Turn to page 15 on the class notebook, and have the students turn to page 15 in their notebooks. Explain that we are going to examine the results of four engineers who are studying the power output of different natural gas power plants. Have the students independently annotate the graphs and draw trend lines. While they are doing this, have volunteers walk around and help students. In addition, annotate the changing variable and data on the graphs (do not underline Natural Gas Amount, Number of Workers, and Number of Generators yet) and draw on trend lines in the class notebook. Once the majority of students are done, put the class notebook under the document camera for them to check their work.

Tell students that for Graph 1 Natural Gas Amount, Number of Workers, and Number of Generators appear in the title and ask them, “Do you see anything else that should be underlined, circled, or boxed?” If they do not know what to do, show them the table under Graph 1 that shows all of these as controls and then underline them. Tell students that for Graph 2 you see Number of Generators in the title, and ask them, “Should Number of Generators be underlined, circled, or boxed?” Then, underline Number of Generators. Ask students, “Why do you think that Graph 1 has all the controls in the title, but Graph 2 only has one of them?” Make sure by the end of the conversation that students understand that for Graph 1 all the controls had different control values, therefore, they all needed to be in the title. However, for Graph 2, the engineers had two common control values (Number of Workers and Natural Gas Amount), so they did not need to put these in the title. Tell students when a team of engineers choose control values all together, they are called “team controls” and when subgroups within a team
choose control values that differ from each other they are called “subgroup controls.” Underneath the Graph 2 controls table have students tell you if each of the controls is a team control or a subgroup control and label them. Tell the students that when a team of engineers has only one subgroup control, they can label the trend lines with the subgroup control values to distinguish them. In the right margin of Graph 2, write “# generators” and label the two lines with the corresponding subgroup control values.

Ask students, “Does the percent water amount affect the power output of the power plant and how do you know?” Possible student response: yes, because all four trend lines show a downward trend. Students should fill out the sentence frame: As percentage of water increases, the power output decreases (4a). Make sure students understand that both graphs are valid to show that percent water amount has an effect on the power output.

Tell the students, “Let’s see if we can predict the power output if we build a power plant that uses 70% of the water, burns 3,200 Mg of natural gas, has 8 workers, and 2 generators.” Tell them that we are not worried about the changing variable value since the scale ranges from 0-100%. Walk them through each of the control values in question and ask them which trend line on each graph has the appropriate control values that match these. The students should tell you that the black circle and both of the triangle trend lines correspond to 3,200 Mg of natural gas, but only the black circle trend line also has the 8 workers and 2 generators as controls. Tell students we will use this trend line to estimate the power output. Ask students, “Where does 70% water amount appear on the x axis?” They should respond, “Halfway between 60% and 80%.” Put a small hash mark at 70% and label it. Remind students that to estimate the power output at these specifications, we will use the black circle trend line. Place your ruler vertically on the graph going from 70% water amount up to the black circle trend line and draw a dashed line. Have students do the same. Next, lay your ruler horizontally starting at the intersection point of your dashed line and the black circle trend line. Draw another dashed line tracing back to the y axis. Tell students that the point their dashed line touches on the y-axis is their power output estimation. Ask students, “What is the amount of power produced by this plant?” Possible student response: 51 MW. Then, write the value down for question 4b. Tell students that because these are predictions, they are approximate numbers. As long as they are within 2 MW of your estimated power, they have drawn an acceptable estimation line and can consider their power correct. If anyone did not get within 2 MW of your estimated power, have a volunteer go and check their graph/trend line. Ask students, “Why are trend lines important?” Possible student response: we can use trend lines to make predictions from our graphs. Record this answer for question 4b.

Read question 4c to the students (Can you predict what the power output would be if the engineers studied a power plant that used 60% of the water, burned 3,200 Mg of natural gas, had 10 workers, and 3 generators in the power plant?) Ask students, “Would both of these graphs be equally useful to make predictions about future experiments?” Allow students to share their thoughts (at this point they might not be able to tell you the answer). After students have shared their ideas, point out that the natural gas amount and number of workers are team controls (the same values) in Graph 2. Walk through each of the control values in question and ask them which trend line has the appropriate control values. Student will be able to narrow the options to the black and white triangle trend lines on Graph 2 but should notice that the number of generators does not match. Ask students, “What do you notice about the trend lines for the black and white triangles?” Possible student response: the trend lines do not cross. Remind students that the team that produced Graph 2 had 2 control values they kept the same and only differed in the number of generators (2 and 4 generators). Ask students, “Where the number 3 falls in relation to 2 and 4?” They should reply, “It’s right in the middle.” Tell students that because the trend lines for 2 and 4 generators do not cross, we can estimate the trend line for 3 generators since it falls between the other two trend lines. Ask students, “By estimating the trend line for 3 generators, will we be able to predict the power output for the power plant with these specifications?” They should say yes and circle YES in their notebooks. Ask them, “Which graph is more useful for us to make our predictions?” They should say Graph 2 because the control values match and the trend lines do not cross and circle 2 in question 4c.
Tell students that you will now show them how to use Graph 2 to estimate the trend line for 3 generators. Tell students that because 3 is exactly between 2 and 4, we can draw a dot on the axes right between the 2 and 4 generator trend lines and then use a ruler to draw a dashed line for where we estimate the 3 generator line should lie. Now that we have a line with all of the values of the controls in the question, we can find the power produced by the power plant. Show the students how to draw a vertical dashed line up from 60% on the x-axis to the new trend line. Then, show them how to draw a flat horizontal dashed line over to the y-axis to find the estimated power output (73 MW). Remind students that these are approximate numbers, so if they are within 2 MW of the number that you write in the class notebook, they should consider their power correct. Have students fill out question 4c with their predicted power output. Ask students, “What did the scientists do that made Graph 2 more useful and what does it mean for your experimental design?” Make sure that by the end of the conversation, students understand that they need to collaborate with groups with the same changing variable when they select their control values. Add this point to the class findings list under “Experimental Design” (page 2, picture packet). An example filled out page 15 (left) and complete findings list (right) are shown below.

**Analysis Activity:**
(20 minutes – Full Class – SciTrek Lead)

Turn to page 16 in the class notebook under the document camera, and have students turn to page 16 in their notebooks. Tell students that we will continue discussing the engineers who studied the effects of natural gas amount, number of workers, and water amount on the amount of power that natural gas power plants produce. They collected data by dividing into three teams, each choosing one of the variables as their changing variable. In addition, they all choose to keep the number of generators running in the plants constant at 3. Give students time to annotate the graph, draw on trend lines, and label the trend line with the subgroup control values on their own while you do the same in the class notebook. When the majority of students are done, put the class notebook under the document camera for them to check their work.
Ask students, “What is the changing variable Team 1 tested? They should reply, “Percent natural gas amount.” Point out that number of workers was a team control and water amount was a subgroup control. Ask the students, “Do you see a trend and, if so, what does this mean?” Possible student response: there is a trend and it means that natural gas amount affects the power output. Then, ask students, “What happens to the power output when the percentage of natural gas amount increases?” They should reply, “Power output increases.” Fill in the sentence frame under question 1a and have students do the same in their notebooks.

Tell the students we are going to use Team 1’s data to predict the power output if we were to change different amounts of each variable. Point out question 1b and read the quantities that will be used from the chart. Ask students, “Do we need to consider the number of workers and why?” Possible student response: no because the number of workers is 9, which is a team control value. So, we just need to focus on water amount. Tell students to look at the water amount values that Team 1 tested (4,000 L, 4,400 L, and 4,800 L) and compare them with the water amount in this question (4,000 L). Ask students, “Which experiment/trend line will we need to look at and why?” Possible student response: we should look at the black circles, because 4,000 L of water were used in that experiment. Circle the black circle. Have students look at the trend line for the black circles. Ask students, “What is the percentage of natural gas that we are interested in?” They should reply, “50%.” Find 50% on the x-axis and use the ruler to draw a dashed line straight up to the trend line for the black circles. Then, find the predicted power output by using the ruler to drawing a second dashed line straight across to the y-axis. Show students that this will give you 85 MW. Remind them that they can be off by up to 2 MW and, if this is the case for them, they should consider their answer correct. Write this on the class notebook and have students copy it into their notebooks.

For question 4c, follow the same process. Ask students, “Do you need to consider number of workers and why?” Possible student response: no because the value is the team control value. Tell students to compare the water amount values that Team 1 tested (4,000 L, 4,400 L, and 4,800 L) with the water amount in this question (4,200 L). Ask students, “What trial or trials do we need to look at and why?” Possible student response: the white and black circles because 4,200 L is halfway between 4,000 L and 4,400 L. Tell students we will have to approximate where this trend line will be. Have students use the same technique as they did in the previous Technique Activity to draw the dashed, estimated trend line. Ask students, “What should we do next now that we have estimated our trend line?” Possible student response: find 70% of natural gas amount on the x-axis and draw a dashed line up to the estimated trend line. Have students do this in their notebooks while you do it in the class notebook. Ask students, “What should we do next?” Possible student response: draw a dashed line straight across to the y-axis and read the expected power output. Have students do this in their notebooks while you do it in the class notebook. Ask students, “What will the estimated power output be?” They should reply, “105 MW.” Write this number in the class notebook. An example filled out page 16 is shown below.
Turn to page 17 in the class notebook under the document camera while students turn to page 17 in their notebooks. Give students time to annotate the graph, draw on trend lines, and label the trend lines with the subgroup control values on their own while you do the same in the class notebook. When the majority of students are done, put the class notebook under the document camera for them to check their work.

Ask students, “What was the changing variable that Team 2 tested?” They should reply, “Percent number of workers.” Point out that water amount is a team control and natural gas amount is a subgroup control. Ask the students, “Do you see a trend and what does this mean?” Possible student response: there is not a trend, and this means that number of workers does not affect the power produced by the power plant. Circle NO on question 2a and have students do the same in their notebooks. Since there is no trend, the sentence frame in 2a does not need to be filled in.

Give students time to fill out questions 2b and 2c on their own. While they are working on these, have the volunteers walk around and help students. In addition, draw on the estimated trend line on the graph in the class notebook. Once the majority of students are done, put the class notebook under the document camera and go over the answers with students. An example filled out page 17 is shown below.
Note: You must finish through page 17 today, otherwise there will not be enough time on Day 5. If there is still time on Day 4, continue working on the Analysis Activity on pages 18 and 19. This will make Day 5 easier. For detailed instructions on how to do this, see the Analysis Activity instructions on Day 5.

Wrap-Up:
(2 minutes – Full Class – SciTrek Lead)

Tell the students that during the next session they will design new experiments using the techniques they learned today.

Clean-Up:

Before you leave, have students attach their nametag to their notebook and place them in the group box. Bring all materials back to UCSB. In addition, put your lab coat into your group box.

Day 5: Analysis Activity/Discussion/Question/Materials Page/Experimental Set-Up/Procedure

Schedule:
Introduction (SciTrek Lead) – 2 minutes
Analysis Activity (SciTrek Lead) – 18 minutes
Discussion (SciTrek Lead/Volunteers) – 15 minutes
Question (SciTrek Volunteers) – 5 minutes
Materials Page (SciTrek Volunteers) – 2 minutes
Experimental Set-Up (SciTrek Volunteers) – 5 minutes
Procedure (SciTrek Volunteers) – 11 minutes
Wrap-Up (SciTrek Lead) – 2 minutes
Materials:

(3) Volunteer Boxes:
- ☐ Student nametags
- ☐ Student notebooks
- ☐ Volunteer instructions
- ☐ Volunteer lab coat

☐ Team plan page
- ☐ (3) Experiment 2 materials pages
- ☐ (2) Pencils
- ☐ (2) Red pens
- ☐ Highlighter
- ☐ Notepad
- ☐ (12) Clear rulers

Lead Box:
- ☐ (3) Extra student notebooks
- ☐ Lead instructions
- ☐ Solar Power picture packet
- ☐ Lead lab coat
- ☐ (2) Team plan pages
- ☐ (3) Experiment 2 materials pages
- ☐ Time card
- ☐ (2) Pencils
- ☐ (2) Red pens
- ☐ Wet erase markers
- ☐ Highlighter
- ☐ Notepad
- ☐ (5) Clear rulers
- ☐ Subgroup fair sticks (in Ziploc)

Notebook Pages and Picture Packet Page:

---

3. Directions: Annotate the graph, draw trend lines for each experiment, and label trend lines with subgroup control values.

![Graph 1](image1)

- a) Does percentage of water affect the power output of the plant?
  - If YES, describe the trend by filling in the following sentence frame:
  - As the percentage of water increases, the power output __________

- b) What power output would you expect to measure if you studied a power plant with the following specifications?
  - Natural Gas Amount: 3,000 Mg
  - Water: 3 L
  - Number of Workers: 8
  - Expected Power Outputs: 95 MJ

- c) What power output would you expect to measure if you studied a power plant with the following specifications?
  - Natural Gas Amount: 3,000 Mg
  - Water: 5 L
  - Number of Workers: 10
  - Expected Power Outputs: 87 MJ

![Graph 2](image2)

4. Directions: Annotate the graph, draw trend lines for each experiment, and label trend lines with subgroup control values.

![Graph 3](image3)

- a) Using both of the graphs above, what power output would you expect to measure if you studied a power plant with the following specifications?
  - Natural Gas Amount: 2,600 Mg
  - Water Amount: 4,600 L
  - Number of Workers: 8

- b) What experiment(s) do you need to look at?
  - Team 1: ☐ ☐ ☐
  - Team 2: ☐ ☐ ☐
  - Team 3: ☐ ☐ ☐

- Expected Power Outputs: 36 MJ

- Team 1 Prediction: 36 MJ
- Team 2 Prediction: 35 MJ
- Team 3 Prediction: 35 MJ

---
### CLASS PLAN

**Subgroup:** the original people you worked with.

**Team:** multiple subgroups that are investigating the same changing variable.

**Changing Variable:** each subgroup picks multiple values on their own.

**Subgroup Controls:** each subgroup picks one value on their own.

**Team Control:** the team picks one value together for all subgroups within the team.

**Class Control:** a team control in which the whole class picks one value together for all teams to use.

**Light Source/Lamp**

#### Team Panel Angle

<table>
<thead>
<tr>
<th></th>
<th>Orange 1</th>
<th>Orange 2</th>
<th>Orange 3</th>
<th>Blue 1</th>
<th>Blue 2</th>
<th>Blue 3</th>
<th>Green 1</th>
<th>Green 2</th>
<th>Green 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange 1</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Orange 2</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Orange 3</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

#### Team Shading Amount

<table>
<thead>
<tr>
<th></th>
<th>Orange 1</th>
<th>Blue 1</th>
<th>Green 1</th>
<th>Orange 2</th>
<th>Blue 2</th>
<th>Green 2</th>
<th>Orange 3</th>
<th>Blue 3</th>
<th>Green 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange 1</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Orange 2</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Orange 3</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

#### Team Temperature

<table>
<thead>
<tr>
<th></th>
<th>Orange 1</th>
<th>Blue 1</th>
<th>Green 1</th>
<th>Orange 2</th>
<th>Blue 2</th>
<th>Green 2</th>
<th>Orange 3</th>
<th>Blue 3</th>
<th>Green 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange 1</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Orange 2</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Orange 3</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

### QUESTION

**Question our group will investigate:**

- If we change the **shading amount**
  - what will happen to the **amount of power produced by the solar panel** (keep what you are measuring (shading) constant).

### EXPERIMENTAL SET-UP

Determine the values of your changing variable(s) (Ex: Panel Angle) from the materials page and write the values (Ex: 45°) for your four trials under each solar panel.

**Changing Variable(s):**

- Shading Amount: 9/8, 9/8, 7/8, 5/8

Why did your subgroup choose these values of the changing variable? *We spread out our changing variable values so our data points will also be spread out.*

### PROCEDURE

**Procedure Note:**

Make sure to include all values of your changing variable(s) in the procedure. (For example, for a group that decided to change panel angle one step would be: Place the panel at an angle of 15°, 30°, 45°, 60°, and 75°.)

1. Place shading 100% in solar panels at 15°, 30°, 45°, 60°, and 75° shaded, and put panel into tray.
2. Place the panels at an 85° angle.
3. Use spacing tool to position panels directly under lamp, and turn lamp on.
4. Do not heat the solar panel, leave at RT.
5. Measure the current (mA) and voltage (V) produced by the solar panel using a multimeter.
6. Calculate the power produced by the solar panel.
7. 
8. 

SciTrek Member Approval 86
Preparation:

SciTrek Lead:

If the classroom has a document camera, ask the teacher to use it for the Analysis Activity (pages 18-19, student notebook) and class plan discussion (page 3, picture packet). If the classroom does not have a document camera, then tape up the poster-size notebook pages on the front board.

Make sure volunteers know what team that they will work with once students form teams.

SciTrek Volunteers:

Set out student notebooks and rulers.
- If students are not in the classroom before SciTrek starts, set out the notebooks where students should sit when they come into the classroom.
- If students are in the classroom before SciTrek starts, pass out notebooks to them; they will move to their subgroup seats after the Analysis Activity.

Introduction:

(2 minutes – Full Class – SciTrek Lead)

If needed, have the SciTrek volunteers hand out the notebooks/nametags to students in their seats. They will move into their subgroups after the Analysis Activity.

Ask the class, “What is the class question that we have been investigating?” Students should reply, “What variables affect the power produced by a solar panel?” Tell the students that today they are going to continue developing analysis techniques and use these skills to plan their next investigation as a class. They will then break into teams to design their experiments.

Tell students that we will continue discussing the engineers who studied the effects of water amount, natural gas amount, and number of workers on the amount of power produced by natural gas power plants. Remind students that the engineers collected data by dividing into three teams, each choosing one of the variables as their changing variable. Ask students, “Did the number of workers affect the power output of the power plant and how do you know?” Possible student response: no, because the trend line is flat.

Analysis Activity:

(18 minutes – Full Class – SciTrek Lead)

Turn to page 18 in the class notebook under the document camera, and have students turn to page 18 in their notebooks. Give students time to annotate the graph, draw on trend lines, and label the trend lines with the subgroup control values on their own while you do the same in the class notebook. When the majority of students are done, put the class notebook under the document camera for them to check their work.

Ask students, “What is the changing variable that Team 3 tested? They should reply, “Percent water amount.” Point out that number of workers is a team control and natural gas amount is a subgroup control. Remind students number of generators is also a team control, and all teams are using 3 as the team control value. Ask students, “Is there any information that we do not need to worry about and why?” If students are struggling, ask them what Team 2 discovered. Possible student response: we do not need to worry about the number of workers because it does not affect the power output. Tell students that they should cross off number of workers and its values on the control chart on this page to remind us that we do not need to worry about this variable. Point out that this is helpful because now we can focus on just one control, natural gas amount.
Ask students, “Do you see a trend and what does this mean?” Possible student response: there is a trend and it means that the water amount affects the power output of the power plant. Then ask students, “What happens to the power output when the percentage of water amount increases?” They should reply, “The power output decreases.” Fill in the sentence frame under question 3a and have students do the same in their notebooks.

Give students time to fill out questions 3b and 3c on their own. While they are working on these have the volunteers walk around and help students. In addition, draw on the estimated trend line on the graph in the class notebook. Once the majority of students are done, put the class notebook under the document camera and go over the answers with students. An example filled out page 18 is shown below.

Turn to page 19 in the class notebook under the document camera, and have students turn to page 19 in their notebooks. Tell students that the engineers are now interested in looking at all of the teams’ data together to make predictions about the power output for different combinations of the variables in the power plants. Tell students that you have copied the Team 1 and Team 3 graphs onto this page so that we can look at the data at the same time. Have the students annotate the graphs, draw trend lines, and label the trend lines with subgroup control values.

Ask students, “Why do you think Team 2’s graph is not printed here?” Possible student response: Team 2 found out that the number of workers did not affect the power output, so we do not need to worry about Team 2’s graph to predict other power outputs. Then, ask students, “Is there any irrelevant information that we could cross out on the charts on this page and why?” Possible student response: you could cross off the number of workers because this did not affect the power output. Cross off number of workers in the class notebook and have students do the same in their notebooks.

Read the directions for question 4a (using both graphs above, what power output would you expect to measure if you studied a power plant with the following specifications?) and read the specifications of the power plant that will be studied from the chart. Tell the students we are going to use Team 1’s data to
predict the power output using the specifications provided, and then we will use Team 3’s data to make a prediction about the same specifications. Then we will compare the two predictions to make a final prediction that takes all of the pertinent data into account.

Look at the Team 1 graph and read the specifications of the power plant from the chart again. Tell students we should focus on water amount first because it is a subgroup control for this team. Tell students to compare the water amount values that Team 1 tested (4,000 L, 4,400 L, and 4,800 L) with the amount of water in this question (4,600 L). Ask students, “Which experiment(s)/trend line(s) will we need to look at and why?” Possible student response: the white and gray circles, because 4,600 L is between 4,400 L and 4,800 L. Circle the gray and white circles. Ask students, “Where do we need to draw the estimated trend line?” Possible student response: the estimated trend line should be halfway between the lines for white and gray circles. Have students use the same technique as for the Technique Activity to draw the dashed, estimated trend line. Ask students, “What should we do next?” Possible student response: find 45% of natural gas amount on the x-axis and draw a dashed line straight up to the dashed trend line. Have students do this while you do it in the class notebook. Ask students, “What should we do next?” Possible student response: draw a dashed line straight across to the y-axis and read the estimated power output. Have students do this while you do it in the class notebook. Ask students, “What power will the power plant produce based on these specifications?” They should reply “~36 MW.” Write this number in the class notebook as the Team 1 prediction.

Tell the students we are now going to use Team 3’s data to make a prediction about the power output using the same specifications. Give students time to try this on their own. While they are working, have the volunteers walk around and help students. In addition, draw on the estimated trend line and predict the power output for Team 3 on the graph in the class notebook. Once the majority of students are done, put the class notebook under the document camera and go over the answers with students. The Team 3 prediction should be ~35 MW.

Ask students, “Which team’s prediction should we use for our final expected power output?” Lead students to understand that we want to use a combination of both team’s predictions to make our final prediction. Since Team 1 predicted a power output of 36 MW and Team 3 predicted 35 MW, we will take the approximate expected power output to be 35.5 MW. Write this number in the class notebook in the box for expected power output, and have the students write the power outputs they predicted in their notebooks. Remind the students that their predictions can differ from the one in the class notebook by up to 2 MW. An example filled out page 19 is shown below.
Class Plan Discussion:
(7 minutes – Full Class – SciTrek Lead)

Place the class plan page (page 3, picture packet) under the document camera. Tell the class they are now going to begin planning their next investigation. Tell the class they will soon split up into teams to collaborate and work on answering the class question, just like the engineers in the Analysis Activity did. Remind students that the groups they worked with on their first experiments were called “subgroups.” Tell students each subgroup will decide which changing variable they want to study in their next experiment. Then, subgroups interested in the same changing variable will join together to form a “team.”

Ask students, “How many variables are we investigating?” They should respond, “Three: panel angle, shading amount, and temperature.” Ask students, “Should subgroups pick their controls independently and why?” Possible student response: no, because subgroups that are investigating the same changing variable need to collaborate so that we can get more information from the data. If they are struggling with this concept, turn to page 15 of the class notebook and review the graphs before and after the engineers collaborated.

Tell students that the engineers in the Analysis Activity chose to keep the number of generators the same for all experiments done by all three teams so they would be able to compare data between them. Ask students, “Do you think we should do something like this too, and if so, what should we have as our ‘Class Control’?” Lead students to understand that the entire class should keep the light source the same which will make it a Class Control”. Write “Light Source/Lamp” under “Class Controls” on the class plan page (page 3, picture packet) under the document camera.

Tell the students they will now form teams to investigate the three variables. Tell students we need to study all three variables, so we will have one team for each variable. Tell students we also need to make sure we collect enough data to learn about each variable, so each team needs to have ~3 subgroups. Give subgroups 1-2 minutes to discuss which changing variable they want to investigate and rank their choice.
of variable (1-3). Then, randomly select subgroups to choose their teams (you can use the subgroup fair sticks in the lead box to randomly select subgroups). Record which subgroup will be in each team by checking subgroup boxes on the class plan page as they select their team. Make sure that subgroups are evenly distributed between teams. Leave the class plan page under the document camera until the end of the team plan discussion. An example filled out class plan page is shown below.

Team Plan Discussion:
(8 minutes – Teams – SciTrek Volunteers)

The Lead will assign each volunteer to a team. Have subgroups find their teams and have the teams move to sit with their volunteer(s).

Help your team fill out the team plan page found in your group box. First, have each of the subgroups on your team choose one of the three symbols. Write the subgroup color and number next to the symbol they select (Ex: X Green 2). Have the students tell you what changing variable they are investigating and if you should underline, circle or box it. Circle that variable on the team plan page. Ask students, “What should we do with the rest of the variables and why?” Students should reply, “Underline them because they are controls.” Then underline the rest of the variables. Find the changing variable (which should be circled) and check the changing variable box. Subgroups will choose values of the changing variable when they fill out the experiment 2 materials page later today.

Next, ask your team, “Would you like to have one of the other variables be a subgroup control?” If needed, remind them the definition of subgroup control, which will be on the class plan page under the document camera for reference (Note: if shading amount is the team’s changing variable, they must use panel angle as their subgroup control). Check the subgroup control box for the variable they chose, and have each subgroup choose a value. Encourage the whole team to work together so that subgroups pick values that are spread out. Write each subgroup’s control value on the line next to their symbol.
The remaining variable will be a team control (again, refer to the class plan page for the definition of team control if needed). Check the team control box for the remaining variable and have the team choose one value for that variable (Note: if shading amount is the team’s changing variable, they must choose room temperature (RT) as their team control value for temperature).

When your team is finished filling out the team plan, make sure that there is only one box checked for each variable and all control values are recorded with the correct units. Highlight each checked box to make it easier to see which variables are the team control, the subgroup control, and the changing variable. Hold onto the team plan page to help the subgroups on your team fill out their experiment 2 materials pages later today. An example filled out team plan page is shown below.

**Question:**
(5 minutes – Teams – SciTrek Volunteers)

Have each student write their subgroup symbol on the front cover of their notebooks. Ask your team, “What changing variable are we investigating?” Refer to your team plan page if needed. Then, ask your team, “What will we be measuring?” Students should reply, “Amount of power produced by a solar panel?” Your team should briefly discuss why/how they think their changing variable will affect the power output.

After your team has recalled their changing variable, have them fill out their question While students are working on their questions, fill out the top portion of your team’s experiment 2 materials pages (found in your group box) with each subgroup’s color, number, and symbol. Refer to the team plan page for subgroup symbols. Students will now split into their subgroups to design their own experiments. Give each subgroup their experiment 2 materials page after you sign off on their question. An example notebook is shown below.
Materials Page:
(2 minutes – Subgroups – SciTrek Volunteers)

Have subgroups underline their controls and circle their changing variable on the experiment 2 materials page. Then have them use the experiment 2 materials page to determine the values for their changing variable and recall the values they chose as controls during the team plan discussion. If needed, have students refer to the team plan page for the control values. For the changing variable values, have students write the trial letter under the value they select. Ask students to justify the values that they have chosen for their changing variable and if these values will make it easier or harder to answer their question. Subgroups will refer to the team plan page for all of their control values.

Make sure that students have picked panel angles, shading amounts, and temperatures that are within the limitations given on the experiment 2 materials page and that all control values are consistent with the team plan page. An example of an experiment 2 materials page is shown in the Experimental Set-Up section.

Experimental Set-Up:
(5 minutes – Subgroups – SciTrek Volunteers)

Have subgroups use the materials page to fill in their experimental set-ups on page 21 of their notebooks. When you sign off on their experimental set-up, collect the experiment 2 materials page and verify that it is filled out correctly and completely. Having the experiment 2 materials page filled out is essential for students to start their experiments during the next SciTrek visit. An example of an experimental set-up and experiment 2 materials page are shown below.
**Procedure:**

*(11 minutes – Subgroups – SciTrek Volunteers)*

After each subgroup has filled out their experimental set-up, they can start on their procedure (page 22, student notebook). Make sure that students within the same subgroup are collaborating to write the procedure. Keep procedures as brief as possible while still conveying the pertinent information about the experiment (control values, changing variable values, and what data they will collect). An example step for a subgroup that had panel angle as a changing variable would be: “Place the panel at an angle of E) 30°, F) 45°, G) 60°, and H) 75°.” Some subgroups may struggle with writing a procedure. If they are having problems with their procedure, they should look back at their initial procedure on page 7 of their notebooks. If they are still having trouble, you can have these subgroups dictate each step while you transcribe them onto a notepad found in your group box. Give this sheet to the students to copy into their notebooks. Once the students finish, they should raise their hand and get their procedure approved by their volunteer. An example procedure can be seen below.

**Note:** Students in each subgroup can vary the wording in their procedures as long as the steps are in the same order and correct values are included. 6th grade students are more independent and capable of writing procedures on their own, so as long as the necessary information (all control and changing variable values and data collection) is included, the wording does not have to exactly match.

If subgroups have extra time, have them fill out their results table.
**Wrap-Up:**

* (2 minutes – Subgroups – SciTrek Lead) *

Tell the students that during the next session they will carry out the experiments that they designed today, graph their data on a team graph, and analyze the data to draw conclusions.

**Clean-Up:**

Before you leave, have students attach their nametag to their notebook and place them in the group box. Place the materials pages and team plan page on top of the notebooks in your group box. Bring all materials back to UCSB. In addition, put your lab coat into your group box.
Day 6: Results Table/Experiment/Graph/Conclusion

Schedule:

- Introduction (SciTrek Lead) – 9 minutes
- Results Table (SciTrek Volunteers) – 3 minutes
- Experiment (SciTrek Volunteers) – 20 minutes
- Graph (SciTrek Volunteers) – 17 minutes
- Conclusion (SciTrek Volunteers) – 9 minutes
- Wrap-Up (SciTrek Lead) – 2 minutes

Materials:

(3) Volunteer Boxes:
- □ Student nametags
- □ Volunteer lab coat
- □ (12) Clear rulers
- □ Student notebooks
- □ (2) Pencils
- □ (3) Solar panel holders
- □ Volunteer instructions
- □ (2) Red pens
- □ Filled out team plan page
- □ Volunteer lab coat
- □ (2) Red pens
- □ Filled out team plan page
- (3) Ziploc bags with the following: (labeled with subgroup number)
- □ Protractor
- □ Spacing tool
- □ Filled out experiment 2 materials page
- □ Solar panel
- □ Shading tool
- □ (2) Binder clips
- □ Multimeter
- □ (2) Binder clips
- □ IR thermometer
- □ (2) Binder clips

Other Supplies:
- □ (2) Boxes of lamps with 6 extension cords
- □ Calculator box
- □ Box with 10 hair dryers

Lead Box:
- □ (3) Extra student notebooks
- □ (2) Red pens
- □ IR thermometer
- □ Lead instructions
- □ (2) Wet erase markers
- □ (2) Multimeters
- □ Solar Power picture packet
- □ (5) Clear rulers
- □ Shading tool
- □ Lead lab coat
- □ (3) Protractors
- □ (2) Tool
- □ Time card
- □ (2) Solar panels
- □ (2) Binder clips
- □ (2) Pencils
- □ Solar panel holder
### RESULTS

**Table**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Trial E</th>
<th>Trial F</th>
<th>Trial G</th>
<th>Trial H</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power Source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panel Angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shading Amount</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Light Source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predictions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent CV (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data</th>
<th>Trial E</th>
<th>Trial F</th>
<th>Trial G</th>
<th>Trial H</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Room Temperature (°C)</strong></td>
<td>22°C</td>
<td>22°C</td>
<td>22°C</td>
<td>22°C</td>
</tr>
<tr>
<td><strong>Current (mA)</strong></td>
<td>5.2 mA</td>
<td>6.8 mA</td>
<td>7.7 mA</td>
<td>7.7 mA</td>
</tr>
<tr>
<td><strong>Voltage (V)</strong></td>
<td>1.9 V</td>
<td>1.9 V</td>
<td>2.0 V</td>
<td>2.0 V</td>
</tr>
<tr>
<td><strong>Power (mW)</strong></td>
<td>99 mW</td>
<td>111 mW</td>
<td>134 mW</td>
<td>154 mW</td>
</tr>
<tr>
<td><strong>Percent CV (%)</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Allowed values for each variable:**
- Power Source: 1 solar panel, 2 solar panels, 3 solar panels, 4 solar panels
- Panel Angle: 50°
- Shading Amount: 0°
- Temperature: 22°C
- Light Source: Low

### Results Graph

Set up your graph. (Check off the steps as you complete them.)

- Enter the title for your graph by filling in the blanks. (The first blank should be Percentage of Power Source.)
- Plot the data collected by the other subgroups in your team by writing their subgroup control value next to your subgroup symbol.
- Draw the legend for one of the other subgroups in your team by writing the subgroup control symbol next to your subgroup symbol.
- Draw a trend line that best fits your data.

### Effects of Percent Power Source and Panel Angle on the Power Output

**Legend**
- Power Source: Solar panel
- Panel Angle
- Shading Amount
- Temperature
- Light Source: Lamp

### Predictions
- S
- L

### Results Table

<table>
<thead>
<tr>
<th>Variables</th>
<th>Trial E</th>
<th>Trial F</th>
<th>Trial G</th>
<th>Trial H</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power Source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panel Angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shading Amount</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Light Source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predictions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent CV (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data</th>
<th>Trial E</th>
<th>Trial F</th>
<th>Trial G</th>
<th>Trial H</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Room Temperature (°C)</strong></td>
<td>22°C</td>
<td>22°C</td>
<td>22°C</td>
<td>22°C</td>
</tr>
<tr>
<td><strong>Current (mA)</strong></td>
<td>0.2 mA</td>
<td>0.4 mA</td>
<td>0.6 mA</td>
<td>0.8 mA</td>
</tr>
<tr>
<td><strong>Voltage (V)</strong></td>
<td>1.1 V</td>
<td>1.4 V</td>
<td>1.5 V</td>
<td>1.4 V</td>
</tr>
<tr>
<td><strong>Power (mW)</strong></td>
<td>0.22 mW</td>
<td>0.94 mW</td>
<td>0.89 mW</td>
<td>0.89 mW</td>
</tr>
<tr>
<td><strong>Percent CV (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Allowed values for each variable:**
- Panel Angle: 50°
- Shading Amount: 0°
- Temperature: 22°C
- Light Source: Lamp

The independent variable is the changing variable and the dependent variables are the current, voltage, and power.
Preparation:

SciTrek Lead:

If the classroom has a document camera, ask the teacher to use it for the results table and graph (pages 4 and 5 (or 6), picture packet and pages 23 and 24, student notebook). If the classroom does not have a document camera, then tape up the example poster-size notebook pages to the front board.

Open the class notebook to page 24 (results graph) and make sure that “Power Source/Solar Panel” is crossed off under the team controls list.

SciTrek Volunteers:

Set out student notebooks.

- If students are not in the classroom before SciTrek starts, set out the notebooks where students should sit when they come into the classroom.
- If students are in the classroom before SciTrek starts, set out the notebooks where students should sit during the module; they will move to these spots after the introduction.

Plug in extension cords and lamps and place them at each spot your subgroups will work at so they are ready to start their experiment promptly after finishing their results table.

Have all supplies ready so that you can set them out as soon as your subgroups are ready to start. This includes getting the correct number of calculators for each subgroup.
Introduction:
(9 minutes – Full Class – SciTrek Lead)

If needed, have volunteers set out the notebooks/nametags where they would like students to sit. Make sure that students in the same subgroup are sitting together and subgroups in the same team are near each other. Tell students that a notebook will be put on their desk, which is not their notebook and they should not move it.

Ask the class, “What is the class question that we have been investigating?” Students should respond, “What variables affect the power produced by a solar panel?” Inform the class that they will be conducting experiments to answer the class question today. Once the experiment is complete they will plot their data on a team graph and analyze it to determine what conclusions can be drawn from their results. Tell students that their conclusions will help answer the class question.

Tell the students that once they have collected their data, they will display their measurements on a graph (page 24, student notebook). Show them how to make a graph using example data, but make sure they DO NOT copy this data into their notebooks, they will graph your own data. Take out the example results table (picture packet, page 4, shown below on left), and put it under the document camera. Also, have the class notebook open to page 24 to graph the example data using the checklist. Tell students, “For this example experiment, the question was, ‘If we change the power source, what will happen to the amount of power produced by the solar panels?’” Point to the checklist at the top of page 24 of the class notebook and tell students, “In order to make a graph, you will need to follow the checklist shown on page 24.”

Go through the checklist and use the results table in the picture packet (page 4) to show the students how to set up the graph and plot the first two data points on the graph.

Set up your graph. (Check off the steps as you complete them.)

☐ Write the title for your graph by filling in the blanks. (The first blank should be Percentage of changing variable)

Looking at the example results table (page 4, picture packet), ask students, “What was the changing variable?” They should reply, “Power Source.” Tell the students, “Remember in order to compare data between groups, we needed to write our changing variable values as percentages. Because of that, what should we write in the first blank?” They should reply, “Percentage of power source.” Write this in the first blank of the graph title.

Tell students, “In the second blank, we need to fill in the subgroup control. Looking at the top of the results table, what is checked as the subgroup control for this experiment?” They should respond, “Panel angle.” Write this in the second blank. Then, ask students, “What we are all measuring in this experiment?” They should respond, “Power output.” Write this in the last blank of the graph title.

☐ Label the y-axis (vertical) with what you measured in your experiment, including units.

Ask students, “What we are measuring in all of our experiments and what are the units it is measured in?” They should say “The power output in milliwatts.” Write “Power Output (mA)” on the line beside the y-axis.
☐ Label the x-axis (horizontal) with “Percent (your changing variable)” (Ex: Percent Power Source).
   
   Ask students, “What was the changing variable in this experiment?” They should respond, “Power source.” Ask them, “How should we write this on the x-axis according to the graph checklist?” Students should respond, “Percent power source.” Record “percent power source” on the line below the x-axis. Remind students that percentages are unitless, so we do not need to include the units on the x-axis.

☐ Select your subgroup control in the legend by checking the appropriate box. Then put your subgroup control value next to your subgroup symbol.
   
   Direct students’ attention to the legend. Remind students that the subgroup control was panel angle and check the box for panel angle. Refer back to the results table and ask students, “What value for panel angle did this subgroup use?” Student should respond, “75°.” Then, tell students, “We need to write the value next to the subgroup symbol.” Direct students’ attention to the top of the results table and ask them, “What symbol was used by the subgroup for this experiment?” They should respond, “Triangle.” Write 75° next to the triangle in the legend.

☐ List your team controls below the graph.
   
   Tell students, “The other controls left on the results table are the team controls. If temperature is a subgroup control or a team control for your team and you choose to use room temperature, you must record ‘RT’ and the measured room temperature in parenthesis in the legend or on the team controls list.” (Note: When the students are graphing, they should refer back to their experimental set-up page to confirm their team controls.) Show students how to write the team controls/values below the graph. Show them the results table to remind them that temperature was a team control for this experiment how to record the temperature as “Temperature/RT (22°C).”

Plot your Data:

☐ On the x-axis, circle your 4 changing variable values. If a value is not there, write it in. Refer to the results table. Ask students, “What is the smallest changing variable value (1 panel), and what percent of that changing variable is it (25%).” Circle 0 on the x-axis. Show students that you will need to write in the next changing variable value (25%) between 30 and 40 on the x-axis and then circle it. Tell students, “To save time, I will only demonstrate the first two points. You will graph the points for all four of your trials.”

☐ Starting with the smallest changing variable value, determine the power and put your subgroup symbol at the appropriate level. Write the value of the power next to the point.
   
   Demonstrate how to graph the data from the results table. Ask students, “What was the power for the 25% power source?” (9.9 mW) Locate 25% on the x-axis (which should be circled) and trace your finger up to 9.9 mW on the y-axis. Plot the point with a small triangle, since that is the example subgroup symbol, and write 9.9 mW next to the point. Repeat this process for the second point.

☐ Once you have plotted all 4 points, draw a trend line that best fits your data.
   
   Use a clear ruler to draw a trend line to fit the data. Remind students that they should draw the line so that about half the points lie above the line and half lie below it. Additionally, remind students to draw the line so it goes all the way to both ends of the graph.
Plot the data collected by the other subgroups in your team.

Tell students that once they finish graphing their own data, they should have it checked by a volunteer. They will then ask the other subgroups on their team for their data and graph it by following the next three steps:

☐ Complete the legend for one of the other subgroups in your team by writing their subgroup control value next to their subgroup symbol.

☐ Graph the subgroup’s 4 points using their symbol as the markers (you do not need to label these points.) Then draw a trend line that best fits their data.

☐ Repeat the process to graph the data for the third subgroup in your team.

Once students have finished their graphs, they should have three trend lines on their graph (two if the class is small), representing the number of subgroups on the team. Show students the appropriate completed graph on page 5 (if you have a small class that only has 2 subgroups per team, show them the graph on page 6 instead). Point out that on the completed team graph, the legend is completely filled out and all data points are marked with the symbol of the group that collected the data. The two versions of the completed team graph are shown below.
Tell students that once they finish graphing their team results, they should draw conclusions from their results. Ask students, “What is a conclusion?” They should reply, “A conclusion is a claim supported by data.” Tell students, “We are acting like engineers in our activity and engineers try to get the most out of whatever they are building. Because of this, if you find in your experiment that your changing variable affects the power produced by the solar panel, you want to make your claim about producing the most power possible. Additionally, you need to refer to your entire team graph for the claim to verify the trend was the same for all subgroups. When coming up with the supporting data for your claim, you need to refer only to your subgroup’s specific data for values.” Refer to the completed team graph under the document camera (either page 5 or 6, picture packet), point to the x-axis, and ask students what happens to the power output when the percentage of power source increases, based on this team’s data. Possible student response: As the percentage of power source increases, more power is produced. Write this claim into the class notebook in the claim section of the conclusions on page 25. Then tell students they should use at least two convincing data points to support the claim. Ask students, “Which two data points are the most convincing for this experiment?” Possible student response: the largest and smallest values of the power. Tell students that when they are writing their data statements, they should include the percentage of their changing variable and the value of their changing variable. Ask students, “How could we write the data statement using this group’s two most convincing data points?” Possible student response: when 100% of power source was used (4 solar panels), 15.4 mW of power were produced, and when 25% of power source was used (1 solar panel), 9.9 mW of power were produced. Write this data statement into the class notebook in the data section of the conclusions on page 25. An example is shown below.
Tell students that they must have their results table completed before they can start their experiment. Remind students of the following things before allowing them to start:

- Students should take the temperature of the room before starting their experiment.
- Students should use the colored scale of the protractor when determining their panel angle.
- If students are shading their solar panel, shading amount increases from the bottom of the solar panel ($\frac{0}{12}$) to the top of the solar panel ($\frac{12}{12}$).
- If students’ subgroup control is temperature, they should heat their solar panel to at least 2° above their goal temperature and wait for the panel to cool down when taking their measurements.
- When taking the temperature of the solar panel, students should angle the thermometer 90° to the panel and shine the light at the center of the panel as indicated by the silver dot.
  - If students are shading their panel more than $\frac{4}{12}$, they will take the temperature by shining the light at the corresponding silver dot indicated on the shading tool.
- For Team Temperature (temperature as their changing variable), each subgroup should heat their solar panel to the maximum temperature and record the current and voltages as the panel cools back down.

If needed, tell students to get together with their subgroup and start working.

When students are starting their experiments, flip the picture packet to page 4 to show them the properly filled out results table. When students are ready to start their graph, flip the picture packet to the appropriate graph page (page 5 for 3 subgroups per team or page 6 for 2 subgroups per team) to show them a properly filled out graph.
### Results Table:
*(3 minutes – Subgroups – SciTrek Volunteers)*

Have students select their subgroup control by checking one of the boxes and write in their subgroup symbol on the line at the top of page 23. Then have students underline the variables that are controls, circle the variable that is their changing variable, and box the data collection. When writing the values, make sure that for controls, they only write the value of the control in the “trial E” box and then draw an arrow through the remaining trials; for the changing variable, they write the value in each of the boxes.

When students have finished, have them make predictions about the power produced by the solar panel. Have them write an “L” in the box of the trial they think will produce the largest power and an “S” in the box of the trial they think will produce the smallest power. They will leave two of the boxes empty. If they think all trials will produce the same amount of power, have them write “same” over all of the boxes. See example notebook below.

### Experiment:
*(20 minutes – Subgroups – SciTrek Volunteers)*

Once subgroups have finished their results table, give them their requested materials. If students are missing any of their experimental materials, the lead box has extra materials. Have your subgroups show you their first set up so you can approve it before moving on. Verify they have the correct angle of their solar panel by using the colored scale of the protractor to determine the angle. If your group is changing temperature, stay to observe their first trial to make sure it runs smoothly. If temperature is a subgroup control, the subgroup should heat their panel to 2° above their goal temperature and allow the panel to cool to record the current and voltage. If temperature is the changing variable, the group should heat the solar panel to the maximum temperature and take the current and voltage readings as the panel cools down. Make sure the students have assigned themselves roles and know to rotate between trials. One
student should run the hair dryer and thermometer (if applicable), one student should call out the
multimeter measurements (and flip between the current and voltage), and one student should write
down the measurements. Remind subgroups that they will read the current from the setting boxed in
black and the voltage from the setting boxed in silver on the multimeter.

Students should record the current and voltage during each trial but should wait until they have finished
the entire experiment to calculate the power output and percent changing variable for each trial. Help
students calculate their percent changing variable if they are struggling by following the equation guide in
the “Percent CV” box in the Calculations section of the data table. The allowed values for each variable
can be found at the bottom of the results table. Allow the students to keep their materials on their desks
until they finish graphing their results. If there is extra time, they may repeat any trials to check their
results. If your team has things under control, help other subgroups. An example of a properly filled out
results table is shown below.

Graph:
(17 minutes – Subgroups/Teams – SciTrek Volunteers)

Pass out a clear ruler to students when they are ready to make their graph. Help students fill out their
table by having them go through and complete the checklist on page 24. Be sure that students write a
title for their graph by filling in the blanks and label the y-axis with “Power Output (mW)”, the x-axis with
their percent changing variable (Ex: Percent Panel Angle), and the legend with their subgroup control
value. Additionally, make sure students circle their changing variable values on the x-axis (and write them
in if they are not printed on the axis). Once students have their data plotted, they should draw in a trend
line.

Once students have graphed their subgroup’s data they should get the data from the rest of the
subgroups in their team, plot it on their graph, and draw trend lines for each data set. For other
subgroups’ data students, should NOT write the number values of the power on top of the points or circle the percentage changing variable value. An example of a properly filled out graph is shown below.

![Graph](image)

**Conclusion:**
*(9 minutes – Subgroups – SciTrek Volunteers)*

Have students use their graph to look for a trend in their data. Challenge students to think about how their changing variable did or did not affect the power produced by the solar panel.

When writing their conclusion (page 25, student notebook), make sure students start the statement with a claim (statement that can be tested) about the trend or pattern in their data. If their graph shows an increasing or decreasing trend, then that variable affects the power produced by the solar panel. If, on the other hand, their graph showed no trend (a flat line) then that variable did not affect the power produced by the solar panel. Since this is an engineering activity, students’ claims should be focused on the value (or pattern of values) of their changing variable that produced the most power and allows them to make a prediction. An appropriate claim could be: the less shading on the solar panel the more power is produced. This is an appropriate claim because it allows the students to make a prediction about what would happen if new values of their changing variable were introduced and identifies which value would produce the most power.

After generating a claim about the experiment, students will put their supporting data after the “because” to back up their claim. Their supporting data should include at least two pieces of data, typically the minimum and maximum power produced. In addition, it should include both the values of the changing variable and the percentages. Make sure students are using their changing variable values (not trial letters) and specific measurements to support their claim. The supporting data for the previously mentioned claim would be: when the panel was $\frac{5}{8}$ shaded (100%) the power produced was 0 mW and when the panel was $\frac{0}{8}$ shaded (0%) the power produced was 4.8 mW.
Conclusions are still valid, and important, if they show that the changing variable tested did not affect the power output.

Example student work for the collusion section can be seen below.

Next, have students fill in the sentence frame: “I acted like a scientist when.” Each student’s response should be unique and specific. They should NOT write, “when I did an experiment,” because this is general and applies to all of the students in the class. If students are having trouble with this sentence frame, ask them what they did during each SciTrek visit.

If there is time, have students analyze their team graph to make a prediction from each subgroup’s data. Students are asked to predict what the power output will be if they use 55% of their changing variable. To get started, have students look at their own data on the graph first. They should find 55% on the x-axis, draw a dotted line vertically up to their trend line, and then find the predicted power output by drawing a second dotted line horizontally across to the y-axis. Students should write their predicted power output next to their subgroup symbol in the chart. Have students repeat this process for each of the trend lines on their team graph. All values will likely be different.

**Wrap-Up:**
(2 minutes – Full Class – SciTrek Lead)

Ask the students the following questions:

- How did you act like a scientist during this project?
- What did you do that scientists do?

After having a discussion about how they acted like scientists and talking about how everyone does things that scientists do in their everyday lives, tell students that they will make posters and present their findings during the next session and you are looking forward to hearing about all of their experiments.
Clean-Up:

Before you leave, have students attach their nametag to their notebook and place them in the group box. Make sure that all of the calculators have the covers on and are placed back into the calculator box and the lamps, extension cords, and hair dryers are back in their boxes. Bring all materials back to UCSB. In addition, put your lab coat into your group box.

Day 7: Poster Making/Poster Presentations

Note: Timing is tight on this day. It is possible that students will only get thought two of the three presentations during the allotted time. In this case, the teacher will need to lead the third poster presentation and discussion findings outside of SciTrek time, before the next SciTrek visit.

Schedule:

Introduction (SciTrek Lead) – 2 minutes  
Poster Making (SciTrek Volunteers) – 25 minutes  
Practice Posters (SciTrek Volunteers) – 5 minutes  
Poster Presentations (SciTrek Lead/Volunteers) – 26 minutes  
Wrap-Up (SciTrek Lead) – 2 minutes

Materials:

(3) Volunteer Boxes:

☐ Student nametags  
☐ Student notebooks  
☐ Volunteer instructions  
☐ Volunteer lab coat  
☐ Poster diagram  
☐ (3) Stickers on how to present results table  
☐ Sticker on how to present graph: specific

☐ (2) Pencils  
☐ (9) Paperclips  
☐ (2) Highlighters  
☐ Scissors  
☐ Stapler  
☐ (2) Glues  
☐ (2) Clear rulers  
☐ (12) Sharpened SciTrek pencils (all same color)

☐ (3) Poster parts packs  
☐ (scientists’ names, question, experimental set-up, procedure, results table, results graph, conclusion, ways we acted like scientists, experimental set-up: specific sheet (white), procedure sheet (white), graph: general sheet (white)

Other Supplies:

☐ Poster paper tube

Lead Box:

☐ (3) Extra student notebooks  
☐ Lead instructions  
☐ Solar Power picture packet  
☐ Lead lab coat  
☐ Poster diagram  
☐ Time card  
☐ (3) Stickers on how to present results table

☐ (3) Stickers on how to present graph: specific  
☐ (2) Pencils  
☐ (2) Wet erase markers  
☐ (9) Paperclips  
☐ (2) Highlighters  
☐ (2) Scissors  
☐ (2) Glues  
☐ Stapler  
☐ (3) Clear rulers  
☐ Scotch tape  
☐ (3 each color) Poster part packs

Preparation:

SciTrek Lead:
If the classroom has a document camera, ask the teacher to use it for the Notes on Presentations (page 7, picture packet). If the classroom does not have a document camera, then write the class question on the board, “What variables affect the power produced by a solar panel?” Leave enough room to record student findings under the question.

SciTrek Volunteers:
Set out student notebooks.
- If students are not in the classroom before SciTrek starts, set out the notebooks where students should sit when they come into the classroom.
- If students are in the classroom before SciTrek starts, set out the notebooks where students should sit during the module; they will move to these spots after the introduction.

**Picture Packet Page and Notebook Page:**

<table>
<thead>
<tr>
<th>Notes on Presentations</th>
<th>Notes on Presentations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Notes on Presentations</strong></td>
<td><strong>Notes on Presentations</strong></td>
</tr>
<tr>
<td>What variables affect the temperature change of the reaction?</td>
<td>What variables affect the amount of power produced by the solar panel?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Changing Variables:</td>
<td>Changing Variables:</td>
</tr>
<tr>
<td>Panel Angle (°)</td>
<td>Panel Angle (°)</td>
</tr>
<tr>
<td>Shading Amount</td>
<td>Shading Amount</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>Temperature (°C)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Power output (mW):</td>
<td>Power output (mW):</td>
</tr>
<tr>
<td>8.0</td>
<td>8.9</td>
</tr>
<tr>
<td>7.8</td>
<td>4.2</td>
</tr>
<tr>
<td>7.2</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Summary: Temperature does not affect the amount of power produced by the solar panel.</td>
<td>Question: All of your graphs look like their trend lines will meet at 0 mW. Why do you think that is? Summary: As shading amount decreases (the panel is less shaded), power output increases.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Changing Variables:</td>
<td>Changing Variables:</td>
</tr>
<tr>
<td>Panel Angle (°)</td>
<td>Panel Angle (°)</td>
</tr>
<tr>
<td>Shading Amount</td>
<td>Shading Amount</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>Temperature (°C)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Power output (mW):</td>
<td>Power output (mW):</td>
</tr>
<tr>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>4.9</td>
<td>4.2</td>
</tr>
<tr>
<td>7.6</td>
<td>1.0</td>
</tr>
<tr>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>Summary: As shading amount decreases (the panel is less shaded), power output increases.</td>
<td>Question: Why do all of your group's trend lines look like they are on top of each other? Summary: As the panel is less angled (closer to 0°), more power is produced. Additionally, there was a subgroup analysis and all 3 trend lines lied close to/on top of each other. This helps prove that temperature does not affect the power produced.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Changing Variables:</td>
<td>Changing Variables:</td>
</tr>
<tr>
<td>Panel Angle (°)</td>
<td>Panel Angle (°)</td>
</tr>
<tr>
<td>Shading Amount</td>
<td>Shading Amount</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>Temperature (°C)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Power output (mW):</td>
<td>Power output (mW):</td>
</tr>
<tr>
<td>11.8</td>
<td>9.1</td>
</tr>
<tr>
<td>9.1</td>
<td>5.4</td>
</tr>
<tr>
<td>10.0</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Summary: As the panel is less angled (closer to 0°), more power is produced. Additionally, there was a subgroup analysis and all 3 trend lines lied close to/on top of each other. This helps prove that temperature does not affect the power produced.</td>
<td></td>
</tr>
</tbody>
</table>

**Introduction:**
(2 minutes – Full Class – SciTrek Lead)

If needed, have volunteers set out the notebooks/nametags where they would like students to sit. Make sure that students in the same subgroup are sitting together and subgroups in the same team are near each other. Tell students that a notebook will be put on their desk, which is not their notebook, and they should not move it.

Ask the class, “What is the class question that we have been investigating?” Students should reply, “What variables affect the power produced by a solar panel?” Inform the class that they will work with their teams to create a poster and present their findings to the class. Tell students this is a common practice in science. Scientists go to conferences where they present posters about the experiments they conducted. At these presentations, other scientists give them feedback on their experiments, which allows them to...
return to the lab with new ideas for future experiments. Similarly, this presentation will be their chance to
tell the class what their team has discovered about the class question. Tell students that they should write
as neatly as possible on the poster parts so that the other class members can read their poster.

Tell the students that they will have 25 minutes to make the poster and then 5 minutes to practice
presenting it with their group. Remind students to read from their notebooks when presenting. Tell
students that after practicing, they will return to their normal classroom seats to take notes on the
presentations.

**Poster Making:**
(25 minutes – Subgroups – SciTrek Volunteers)

Each team (6-11 students) will make one poster on their second experiment, so there will be three
presentations total. Every student on the team will have both a writing and a speaking part in the
presentation.

As a team, have students look at all of the graphs and vote on which graph they think is “best” (has the
most convincing data). Then discuss why that data is the most convincing.

Pass out the writing portions (general poster parts, presentation sheets, and “ways we acted like
scientists”) and have students write their names on them and complete them. Make sure that graph:
specific piece and the conclusion are given to students in the subgroup that had the “best” graph. Keep in
mind, the students presenting graph: specific and conclusion must be from the same subgroup. In
addition, have each student write their name on the scientists’ names poster part. Use the following
guidelines when assigning poster parts:

<table>
<thead>
<tr>
<th>Speaking Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Scientists’ Names</td>
</tr>
<tr>
<td>2. Question</td>
</tr>
<tr>
<td>3. Experimental Set-Up: General</td>
</tr>
<tr>
<td>4. Experimental Set-Up: Specific <em>(Staple presentation sheet into notebook, pg. 21)</em></td>
</tr>
<tr>
<td>5a. Results Table □ <em>(Sticker, pg. 23)</em></td>
</tr>
<tr>
<td>5b. Results Table △ <em>(Sticker, pg. 23)</em></td>
</tr>
<tr>
<td>5c. Results Table △ <em>(Sticker, pg. 23)</em></td>
</tr>
</tbody>
</table>
| 6. Procedure *(Give instruction sheet to student and staple presentation piece into
notebook, pg. 22)* |
| 7. Graph: General *(Staple presentation sheet into notebook, pg. 22)* |
| 8. Graph: Specific *(Sticker, pg. 24)* |
| 9. Conclusion |

*Students highlighted in gray must be from the same subgroup (the subgroup with the
most convincing data).
*All students should have a speaking part. Depending on the size of the team it might be
necessary to have students present more than one speaking part or divide speaking parts
into two (Ex: two people present the procedure).

*Give the graph: specific sticker to the student that is most confident in presenting.

Once students have finished their writing section(s), have students add to the “ways we acted like
scientists” poster part. To do this, they can copy their “I acted like a scientist when” statements from page 25 of their notebooks or come up with new ones.

In the students’ notebooks, highlight and number the section(s) that they will present. The parts should be numbered as follows: 1) scientists’ names, 2) question, 3) experimental set-up: general, 4)
experimental set-up: specific (staple sheet), 5a) results table, 5b) results table, 5c) results table X, 6) procedure (staple sheet), 7) graph: general (staple sheet), 8) graph: specific (sticker), and 9) conclusion (see example below). Students will NOT present the “ways we acted like scientists” from their poster. If a student is presenting multiple sections, use the paperclips in your group box to clip together the sections that they are reading so that when presenting, it will be easy to flip back and forth between pages.

Ex: Highlighted and Numbered Notebook Pages

* 5b and 5c are not shown. They are identical to 5a but given to students in different subgroups.
Place the following sentence frame sticker on the notebook page of each of the students that are presenting the results tables (page 23, student notebook):

| We are subgroup __________. Our changing variable is _____________________, and the values we used are __________, __________, __________, and __________. |

Show the students how to fill out the blanks on the sticker from their results table. For example, the sticker for the first results table on the poster below would read: We are subgroup circle. Our changing variable is shading amount, and the values we used are __0/8___, __7/8___, __5/8___, __2/8___. All blanks should be filled out by the student.

Next, place the following sentence frame sticker on the notebook page of the student presenting the graph: specific (page 24, student notebook):

| When the solar panel was ______ % the power output was ______ mW. |

Then practice reading the four sentences with that student. For the poster below, the first sentence would be: When the solar panel was 0% shaded, the power output was 3.1 mW. Make sure you fill in the second blank for the student in the sentence frame but leave the first and third blanks (“percentage” and “power”) empty. The second blank will not be filled in exactly with the changing variable. In order to make the sentence flow, fill in “angled” for panel angle, “shaded” for shading amount, and “heated” for temperature.

The students that are presenting experimental set-up: specific, procedure, and graph: general should all receive white presentation sheets that need to be stapled into their notebooks and highlighted. The experimental set-up: specific sheet will be stapled to page 21, the procedure sheet will be cut and stapled to page 22, and the graph: general sheet will be stapled to page 24. These sheets have instructions on them for how to fill them out, but if needed, show students how to complete them. Examples of properly highlighted notebook pages, presentation sheets, and stickers are shown above.

As soon as students have completed some of their pieces, start gluing them onto the large poster paper, in landscape orientation, exactly as they are arranged in the example below. Do not allow students to glue the poster parts on the poster. Do not wait until students have completed all the pieces to start gluing them onto the poster.

Once the poster is complete, have students start practicing for the presentation. Make sure that students read from their notebooks instead of off the poster.
Ask your team a few questions about their poster. Have them use their findings to predict what would happen to the power output for values of their changing variable that they did not test. For instance, if the team’s conclusion was, “the less shaded the solar panel, the more power the solar panel will produce,” ask the team to predict the power if they shaded 20% of their panel.

If there is additional time, tell your team that the other students will ask them questions during their poster presentations. Tell them that they should think about what questions they will be asked and then think of the answers to those questions so that they will be prepared during their presentation.

**Practice Posters:**
*(5 minutes – Subgroups – SciTrek Volunteers)*

While the volunteers are practicing their poster presentations with their teams, the lead should organize the posters in order of increasing complexity (suggested order: Shading Amount → Panel Angle → Temperature).

Have teams practice their poster presentation, making sure they are reading the poster parts in the correct order (scientists’ names, question, experimental set-up: general, experimental set-up: specific, results table \( \bigcirc \), results table \( \Delta \), results table \( \times \), procedure, graph: general, graph: specific, and conclusion). Make sure each student’s part is highlighted in their notebook. If students are reading from multiple pages, use a paperclip to clip these pages together to make it easier for them to flip back and forth. Remind students to read from their notebook rather than from their poster.

Do not let poster practice go over 5 minutes.

**Poster Presentations:**
*(31 minutes – Full Class – SciTrek Volunteers/SciTrek Lead)*

Have students return to their original class seats. Ask the class, “What is the question that we have been working on solving?” Students should reply, “What variables affect the power produced by a solar panel?” Tell students that during the presentations they are going to take notes. Have them turn to page 26 in their notebook while you turn to page 7 of the picture packet. Tell them that they need to record each
team’s changing variable after the team says their question. In addition, they will record the values of the changing variable as percentages and the measurements when the team presents their graph (specific).

After each presentation, students will be given the opportunity to ask scientific questions to the presenting team to help them determine if/how the variable investigated affected the power output. Every student needs to come up with at least one scientific question per presentation. Tell students that whenever they come up with a scientific question during the presentation, they may write it into their notebook, but they will all be given ~1 minute to write down a question after each presentation. Tell them these questions are important because they will have to record a summary of what they learned from the team. Therefore, their questions should focus on helping them be able to summarize the team’s findings. Tell students that they will receive a SciTrek pencil if they ask/write down a scientific question.

Student notebooks only have room for notes and questions on 2 presentations. Therefore, they will not take notes on their own presentation.

Volunteers should make sure that students are quiet and respectful when other teams are presenting. When your team is presenting, go to the front of the room with them; prompt students if they do not know who talks next and remind them to read from their notebooks. Volunteers should keep track of students that ask/write down scientific questions. Wait until poster presentations are finished to pass out SciTrek pencils.

During the student question time, the lead and/or volunteers should ask at least one question. Examples of possible questions are: “How do you know...?” or “Is there anything else you can do to get more information about your question?” Each team should answer approximately 10 questions (one question per student).

After each presentation have the students tell you which value of each variable they would suggest to an engineer who wanted to produce the most power from a solar panel. Circle that value on the table and have students do the same in their notebook.

- Temperature: Any temperature (do not circle anything).
- Shading Amount: No shading/as little as possible (closer to 0%).
- Panel Angle: The lowest angle possible (closer to 0%).

Below is an example of notes that the lead and students could have taken during the poster presentations.
After all poster presentations have been given, ask the class, “What did we learn about the power produced by a solar panel?” Have them summarize the class findings. The highlights from the experiments are shown below.

- The temperature does not affect the power output.
- The less shaded the solar panel, the greater the power output.
- The less angled the solar panel (angles closer to 30°/0%), the greater the power output.

Tell students they have taught you a lot about the power produced by solar panels. Give students who wrote down and/or asked scientific questions a SciTrek pencil.

**Note:** Timing is tight on this day. It is possible that students will only get through two of the three presentations during the allotted time. In this case, the teacher will need to lead the third poster presentation and discuss findings outside of SciTrek time, before the next SciTrek visit.

**Wrap-Up:**
*(2 minutes – Full Class – SciTrek Lead)*

Tell the students that the volunteers that have been working with them are undergraduate and graduate students that volunteer their time so that they can do experiments. Have the students say thank you to the volunteers. This is the last day with their SciTrek volunteers, therefore, they should say goodbye to them. Tell students that you will be back one more time.

Tell students to remove the paper part of their nametag from the plastic holder and that they can keep the paper nametag, but they need to give the plastic holder back to their SciTrek volunteer.
Clean-Up:

Before you leave, collect the plastic nametag holders and put them in the group box. Students can keep the paper part of their nametag. Collect notebooks and place them in the group box. Leave student posters in the classroom. Bring all materials back to UCSB. In addition, if you will not be attending the Tie to Standards day, remove all materials from lab coat pockets, remove your nametag, unroll lab coat sleeves, and put your lab coat into the dirty clothes bag at UCSB.

Day 8: Analysis Assessment/Tie to Standards

Schedule:

Analysis Assessment (SciTrek Lead) – 10 minutes
Tie to Standards (SciTrek Lead) – 50 minutes

Materials:

Lead Box:
- ☐ (3) Extra student notebooks
- ☐ Student notebooks
- ☐ Lead instructions
- ☐ Solar Power picture packet
- ☐ Lead lab coat
- ☐ (35) Analysis Assessments
- ☐ Time card
- ☐ (2) Pencils
- ☐ (2) Wet erase markers
- ☐ (35) Clear rulers
- ☐ Protractor
- ☐ Solar panel holder
- ☐ Spacing tool
- ☐ Shading tool
- ☐ (2) Binder clips
- ☐ Multimeter

Other Supplies:
- ☐ Bag with 1 lamp, 1 extension cord, and 1 power strip
- ☐ Box of Tie to Standards materials (LED bulb, CFL bulb, Halogen bulb, hanging lightbulb holder, green and white LED cups, amp meter, multimeter with leads, probe leads, black cloth)
TIE TO STANDARDS

6. What is power consumption? The power we use in some time.
7. What would we need to do if we wanted to monitor the power consumption in this classroom? Measure the current and voltage of devices in the room over some time period.
8. Why is it useful for us to be able to monitor the power consumption? To know how much power we are using.
9. What is the main way we monitor our monthly power consumption? Through our power bill.

In California, we are able to produce power from different energy sources. Some are renewable and some are non-renewable.

10. Match the definitions:
   a. Renewable Energy Source: A source that is not replenished as fast as it is consumed (i.e., cannot be replenished within a human's lifetime).
   b. Non-renewable Energy Source: A source that produces energy that is not used up or can be replenished within a human's lifetime.

   Renewable Energy Sources
   - Solar
   - Wind
   - Geothermal

   Non-renewable Energy Sources
   - Coal
   - Natural gas

Effects of Power Use

In the table above, circle all energy sources that are burned to obtain energy.

11. When energy sources are burned, carbon dioxide ($CO_2$) is produced.

WILL LIGHTBULBS WITH THE SAME NUMBER OF LUMENS NEED DIFFERENT AMOUNTS OF POWER TO LIGHT?

<table>
<thead>
<tr>
<th>Type of lightbulb</th>
<th>Voltage</th>
<th>Current</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED</td>
<td>120V</td>
<td>0.01W</td>
<td>1.2W</td>
</tr>
<tr>
<td>CFL</td>
<td>120V</td>
<td>0.15A</td>
<td>12W</td>
</tr>
<tr>
<td>Incandescent/halogen</td>
<td>120V</td>
<td>1.5A</td>
<td>180W</td>
</tr>
</tbody>
</table>

12. Which bulb is the most efficient? The LED, it uses less power to work.

The box for each of the lightbulbs is shown below. Compare the information on the boxes and answer the questions below.

16. Which bulb is the most efficient? The LED, it uses less power to work.

20. What does the life of the lightbulb tell us? The longer the life, the fewer lightbulbs we need.

21. What does the estimated yearly energy cost of the lightbulbs tell us? How much it costs to run the lightbulb.

22. The LED light bulb is best because it uses the least power to work (1.2W), lasts the longest (10 years), and it costs the least amount of money to run ($1.30).
**Preparation:**

**SciTrek Lead:**

If the classroom has a document camera, ask the teacher to use it for the Analysis Assessment and Tie to Standards Activity (pages 27-30, student notebook and page 8, picture packet). If the classroom does not have a document camera, then tape the example poster-size notebook pages to the front board.

If the teacher is not leading the Tie to Standards Activity, give them an extra student notebook and have them fill it out with their students to follow along.

Assemble the Tie to Standards set-ups accordingly:

1. Plug an extension cord into the wall and then plug the power strip into the extension cord. We do not want to accidentally blow a circuit breaker during the brighter choices section of the Tie to Standards Activity, therefore, we must set this up accordingly.

2. Set up the Solar Panel Set Up.
   a. Place a solar panel in the solar panel holder and turn the angle to 50°.
   b. Use the shading tool to shade \( \frac{2}{8} \) of the panel.
   c. Hook the multimeter up to the panel.
   d. Plug the lamp into the power strip.
   e. Place the entire set-up near the document camera.

3. Set up the Bright Choices Set-Up.
   a. Screw the LED bulb into the hanging lightbulb holder and set it in the Tie to Standards materials box.
   b. Have compact fluorescent and halogen bulbs nearby.
Pass out notebooks to students. If you do not have time to get set up before the start of the module, ask the teacher to pass out notebooks.

Remind the teacher to give you their lab coat at the end of the day.

Analysis Assessment:
(10 minutes – Full Class – SciTrek Lead)

“Before we start our activity today, we will determine how your ideas on analyzing and interpreting data are developing. One of the ways that we get program funding is by demonstrating program effectiveness. Therefore, we need you to do your best on the assessment.” Pass out the Analysis Assessment and tell students to fill out their name, teacher’s name, and date on the top of the assessment. Remind the students that it is important that they fill out this assessment on their own.

For page 1, read the directions for annotating to the students. Then, have students annotate the first results table by underlining controls, circling changing variables, and boxing information about data collection. Read question 1b (Can this group make a conclusion?), and have students answer it. Have students annotate the possible conclusion. Finally, read question 1d (Is this a correct conclusion for the results table? If NO what is wrong with the conclusion?) and have students answer the question. Repeat this process for questions 2 and 3.

Pass out the rulers to students. Read the directions for question 4 to the students. Then, have students annotate the graph by underlining controls, circling changing variables, and boxing information about data collection. Have students plot the remaining points on the graph using circles as markers. Then tell students to draw trend lines for each experiment on the graph. Read questions 4d-4f and give students time to answer each. Walk around to make sure students are filling out the questions. After reading the last question, tell students to raise their hands when they are finished so you can collect their assessments. Students should keep their rulers to use during the Tie to Standards Activity.

Tie to Standards:
(50 minutes – Full Class – SciTrek Lead)

Tell students you enjoyed hearing about their experiments last time, and that we should quickly review what we found out as a class. Ask students, “What question were we trying to answer with our experiments?” Students should reply, “What variables affect the amount of power produced by a solar panel?” Ask students, “What is power?” Students should reply, “A measure of energy over time.” Have students open their notebook to page 27 while you open the class notebook to page 27 and place it under the document camera. Have students fill in the definition of power they just gave you for question 1. Ask students, “Why do we care about the amount of power solar panels produce?” Possible student response: devices operate at different amounts of power, and if we can figure out how to position a solar panel to produce a certain amount of power, we can use that solar panel to power our devices.

Predicting Power (15 minutes)

Pass out a calculator to each student.

Tell students, “On the first day of this module we observed how much power it took to light a blue and red LED. Today we will look at a white and green LED.” Direct students’ attention to the turn-on power for each LED at the top of page 27. Tell students, “In order to light a white LED, 64.6 mW of power are needed, and in order to light a green LED, 3.6 mW of power are needed. We will use the graph in question 2 to determine if it will be possible to light each LED using a solar panel at the given specifications.” Read
the directions for question 2. Tell students to annotate the graph and draw and label trend lines on their own and you will do the same. When they have finished, they can check their graph with yours under the document camera. Give students ~2 minutes to complete this before putting the class notebook under the document camera for them to check answers.

Once everyone has finished, ask students, “What was this team’s changing variable?” The students should reply, “Panel angle.” Then, ask students, “What was this team’s subgroup control?” The students should reply, “Shading amount.” Lastly, ask students, “What was this team’s team control?” The students should reply, “Temperature.” Ask students, “What did we learn about temperature from our class experiments?” Possible student response: temperature does not affect the amount of power produced by a solar panel. Ask students, “If this team decided to run their experiments at 35°C instead of room temperature, how would that affect their results?” Possible student response: it should not affect their results since temperature does not affect the amount of power produced by a solar panel.

Ask students, “What did we learn about panel angle from our experiments?” Possible student response: as the panel is less angled, the power output increases. Ask students, “What did we learn about shading amount from our experiments?” Possible student response: as the panel is less shaded, the power output increases. Ask students, “Does this graph show a trend that is consistent with our class findings?” Students should reply, “Yes,” and circle this response to the question under the Graph 1 Controls box.

Read question 3 to the students (using data from Graph 1, what power would you expect to calculate if you used a solar panel that was 2/8 shaded, 33% angled (50°), and at room temperature). Ask students, “If we want to answer this question, which experiment/experiments do we need to look at and how do you know?” Possible student response: the circle and triangle experiments because 2/8 shading falls directly between 0/8 and 4/8 shading. Ask students, “How should we start finding our prediction?” Possible student response: we should draw a trend line halfway between 0/8 and 4/8, and then use that trend line to determine the power output. Have students draw their trend line and determine the predicted power on their own while you do the same in the class notebook. Tell students once they have finished to check their answer with yours. To determine the power output prediction, place your ruler vertically at the 33% mark and draw a dashed line up to your dashed trend line. Then, place your ruler horizontally at the intersection of your two dashed lines and draw another dashed line back to the y-axis. The point at which you hit the y-axis will be the predicted power output. You should predict 7.3 mW. Remind students that their prediction should be within 0.3 mW of the prediction written in the class notebook.

Tell students that we will now test our predictions. Place the multimeter under the document camera and tell students, “First, let’s figure out our actual power output produced by a solar panel at these specifications (2/8 shaded, 33% angled (50°), and room temperature). The solar panel has been set up to these specifications, but to ensure no outside light will affect the results, we will put this black cloth over the set-up.” Turn on the lamp and place the black towel over the lamp and solar panel set-up (the multimeter should be left outside of the cloth, and able to be placed under the document camera). Place the multimeter under the document camera and turn the multimeter dial to the setting boxed in black and have the students read and record the current produced by the solar panel. Turn the multimeter dial to the setting boxed in silver and have students read and record the voltage produced by the solar panel. Ask students, “How do we calculate power?” Students should reply, “We multiply the current and voltage together.” Have students use a calculator to calculate the power output while you do the same under the document camera. Have students check their answer with yours.

Remove the multimeter from under the document camera and turn off the lamp. Next, ask students, “Will this be enough power to light the green LED, and how do you know?” Possible student response: yes, the green LED only requires 3.6 mW of power to turn on. If they are having trouble, direct their attention to...
the top of page 27 where the turn-on power for each of the LEDs is located. Once the class has agreed that this will be enough power to light the green LED, circle “Yes” for question 4. Then, ask students, “Will this be enough power to light the white LED, and how do you know?” Possible student response: No, the white LED requires 64.6 mW of power to light. Once the class has agreed, circle “No” for question 5.

Tell students, “Next we will test these predictions.” Unhook the multimeter from the solar panel and attach the green LED cup via the alligator clips (Remember, the red foot of the LED is clipped to the red lead, and the black foot of the LED is clipped to the black lead). Make sure the black cloth is over the entire set-up, except the LED cup, and turn on the lamp. The green LED should light. Shine the light around the room so every student can see the LED lit up. If they are having trouble telling the LED is lit, place your hand over the solar panel to block the light (the LED should unlight) and remove your hand (the LED should light). Unhook the green LED and attach the white LED in the same manor to the solar panel. The white LED should not light. Again, make sure that each student sees the unlit LED. Unhook the LED and set it aside. An example page 27 is shown below.

Power Sources/Uses (5 minutes)

Tell students, “Now that we understand how to predict power outputs, let’s think about how we use power and where our power comes from.” Have students turn to page 28 in their notebooks while you do the same in the class notebook under the document camera. Ask students, “What is power consumption?” Have the students generate some ideas and lead them to the idea that power consumption is the amount of power we use in some amount of time. Record this for question 6. Ask students, “What would we need to do if we wanted to monitor the power consumption in this classroom?” Possible student response: measure the current and voltage of devices in the room over some period of time. Record this for question 7. Ask students, “Why is it useful for us to be able to monitor the power consumption?” Possible student response: that way we can know how much power we are using. Record this for question 8. Lastly, ask students, “What is the main way we monitor our monthly power consumption?” Possible student response: through our power bill. Record this for question 9. If students are struggling, explain to them that every month, a local power company (Ex: In
Santa Barbara, Southern California Edison) monitors our energy/power usage to determine how much we are consuming. They then send us a bill in the mail that tell us how much energy we used and how much that energy costs.

Tell students, “In California, we are able to produce power from different energy sources. Some are renewable and some are non-renewable.” Read question 10 to the students, “Match the definitions: renewable energy source, non-renewable energy source.” Have students read the definitions to themselves and raise their hand when they think they’ve found the match for each definition. Call on a student to share their answer and see if the class agrees. Once you’ve reached a consensus, draw lines connecting the correct phrase to the correct definition. 1 connects to b and 2 connects to a.

Ask students, “What are some renewable or non-renewable energy sources that you know of?” List the student responses in the table under question 10. Possible student responses can be seen in the picture below.

Note: The three main fossil fuels (fuels formed in the geological past from the remains of living organisms) are coal, oil, and natural gas. Because some students may know this, they might suggest oil as a non-renewable energy source. Crude oil/petroleum can be refined for many uses, including gasoline, kerosene, asphalt, and can be used to make plastics. Because of this, if students suggest “oil” as a potential non-renewable energy source, lead them to understand that the most-used form of oil for energy is gasoline, which is used to power some of our cars.

Note: If students bright up nuclear energy it should be put under a non-renewable energy source because there is only so much uranium-235.

If there is a volunteer in the classroom, have them take down the Solar Panel Set-Up and replace it with the Bright Choices Set-Up. They should replace the alligator clips in the multimeter with the probes, make sure the LED is screwed into the free-hanging lightbulb holder, and place these items, along with the CFL and halogen bulbs and amp meter, next to the lead’s document camera set-up.
Effects of Power Use (15 minutes)

Tell students, “Now that we understand where our power comes from, let’s think about how our power consumption affects the world around us. Remember, power is the measure of energy over time. What form of energy is our solar panel producing?” Students should reply, “Electrical energy.” Ask students, “In order to obtain electrical energy from our solar panel, what did we have to provide?” Possible student response: we had to turn on a lamp. Tell students, “This means that the energy from light can be harnessed by a tool like a solar panel to convert the energy in light into electrical energy for us to use.” Ask students, “If we wanted to obtain electrical energy from wind, another one of our renewable energy sources, what tool would we have to use?” Possible student response: a wind turbine.

Tell students, “To transfer the energy into a form that is useful to us some energy sources have to be burned.” Have students tell you which energy sources are burned in the table and circle them in the class notebook while students circle them in their notebook. All the energy sources in the non-renewable category should be circled (with the exception of nuclear, if applicable). In addition, you might have to circle some renewable sources.

Note: Biofuel is a type of fuel made from biomass (plant matter, algae matter, or animal waste). If you burn wood in a campfire this would be considered a biofuel. Biofuel/biomass may or may not come up with your students. You do not need to bring it up if it does not come up organically.

Ask students, “Do you know of a tool we would use to transfer the energy from energy sources that we burn into useful energy sources?” Students may not know the answer to this question, and that is okay. Lead them to understand that cars (gasoline), power plants (coal and natural gas), and stoves (natural gas) are tools that can be used to harness the energy from fossil fuels.

Tell students, “Whenever one of these energy sources is burned, carbon dioxide is produced. Fill “carbon dioxide (CO₂)” in the blank for question 11.

Note: Nuclear power is produced through a process called fission, in which atoms are split to release heat. This does not require the burning of fuel, and thus does not produce greenhouse gas emissions. However, there are other serious environmental impacts from nuclear energy including nuclear waste.

Turn to page 29 in the class notebook under the document camera while students do the same in their notebooks. Tell students, “Scientists have found a link between carbon dioxide (CO₂) levels and temperature. Using the graphs on the top of page 29, we need to determine what that link is.” Direct students’ attention to the graph titled “Atmospheric Carbon Dioxide Levels.” Ask students, “What is this graph trying to explain?” Possible student response: how carbon dioxide levels have changed over time. Inform students that “ppm” is a unit of measurement called “parts per million,” that essentially refers to how much of a chemical is in some volume. Ask students, “Does this graph have a trend, and, if so, what is it?” Possible student response: yes, there is a trend; in ~1990, the CO₂ levels started to drastically
increase. Direct students’ attention to the graph titled “Atmospheric Temperature Anomalies.” Ask students, “What is an anomaly?” Possible student response: an anomaly is something that is different from the normal. If students are not able to give a definition of anomaly, then give them the definition. Ask students, “What is this graph trying to explain?” Possible student response: How temperatures have changed over time. Tell students (if they do not understand what the data is showing), “A monthly mean temperature anomaly is describing how much the temperature in a monthly deviated from the expected or normal temperature.” Ask students, “Does this graph have a trend, and, if so, what is it?” Possible student response: yes, there is a trend; in ~1910 the temperature anomalies started to increase.

Tell students that we want to make a conclusion from the data. Ask students, “What is a conclusion?” Students should reply, “A claim supported by data.” Ask students, “What claim can we make about the link is between CO₂ levels and temperature?” Possible student response: as CO₂ levels increase, the temperature anomalies also increase. Direct students’ attention to question 12 and fill in the blank, “As CO₂ levels increase, the average atmospheric temperature increases.” Tell students, “We need to determine supporting data for our claim from these graphs. What two points on our graph help convince us that this claim is true?” Possible student response: we could use the point at which the CO₂ level started drastically increasing (~1900) and 2000, which is much after the increase and is clearly marked on our graph. Students do not have to pick the year 2000 as the end point, it is possible to choose others, this is just the most convenient choice. Tell students, “We will use our rulers to help us determine the CO₂ levels and temperature anomalies at the years we determined would be most helpful.” Walk students through determining the CO₂ level at 1900 (~290 ppm) and 2000 (~375 ppm). Have students use the same process to determine the temperature anomalies on the second graph on their own while you do the same in the class notebook. Check answers with the class after ~1 minute. Make sure students understand that when the numbers are below 0, this is telling them that the temperature are below average.

Tell students, “Now that we have our data points, we can put together our data statement.” Have one student share out a possible data statement and have the other students use thumbs up/thumbs down to show agreement over the data statement. If the class is in agreement, write the data statement on the lines following the “because” in question 12. Possible student response: in 2000, there were 375 ppm of CO₂ in the atmosphere and the temperature was 0.5°C above average, and in 1900, there were 290 ppm of CO₂ in the atmosphere and the temperature was 0.1°C below average.

Read question 13 to students and ask, “If California uses non-renewable energy sources for power, what will happen to the amount of CO₂ in the atmosphere, and how do you know?” Possible student response:
it will increase because as non-renewable energy sources are burned, they produce CO₂. Record this answer for question 13. Read question 14 to students and ask, “What will this mean about the average atmospheric temperatures, and how do you know?” Possible student response: They will increase since we know that as CO₂ levels increase, the temperature also increases. Record this for question 14. Ask students, “If we want to minimize the amount of CO₂ we are putting into the air, which types of energy sources should we try to use?” Students should reply, “Renewable energy sources.” Tell students, “In California, 47% of our electrical energy comes from renewable sources,” and record this for question 15.

Note: Biofuels do produce CO₂ when they are burned, but this is considered to be a carbon neutral process. While plants are alive, they take in CO₂ from the air, thus storing carbon in them. When they die/are used as fuel, they release that stored carbon back into the atmosphere as CO₂. Because the net carbon results to zero, the process is considered carbon neutral. When fossil fuels are burned, they release carbon that would normally not be released back into the atmosphere; therefore, this is not a carbon neutral process.

Bright Choices (15 minutes)

Ask students, “We know that by using renewable energy sources we can minimize the impact on the amount of CO₂ we’re putting into the atmosphere. However, we cannot control the power sources being used for our electricity. Is there any way that we can minimize our impact on CO₂ production?” Possible student response: we can reduce our electricity use and use “better” electrical devices. Record this for question 16.

Tell students, “We will now look at three different types of lightbulbs to compare the amount of energy they use to run. This will help us determine which lightbulb is ‘best’ at helping us minimize our impact on our energy usage. The first lightbulb we will look at is called an LED.” Write this in the first blank, then hold the bulb under the document camera for the students to see. Tell students, “The second bulb we will look at is called a compact fluorescent lightbulb; this is abbreviated at CFL.” Write this in the second blank, then hold the bulb under the document camera for the students to see. Tell students, “The third bulb we will look at is called a halogen lightbulb, which is a type of incandescent lightbulb.” Write this in the third blank, then hold the bulb under the document camera for the students to see. Tell students, “There are some important terms we need to understand when looking at lightbulbs. The first is lumens. The number of lumens describes how much light is being given off by the lightbulb.” Record this for question 17. Ask students, “Is the number of lumens important to consider when comparing different types of light bulbs, and why?” Possible student response: yes, the number of lumens is important because we want light bulbs that will all give off the same amount of light. Make sure students understand that the more lumens (the brighter the light bulb) the more energy that would be used. Once the class agrees that this would be important to hold constant, circle “Yes” for question 17.

Tell students, “The second important term to understand is the temperature of the light bulb. In this case, the temperature does not refer to the amount of heat produced by the light bulb, but rather the color of the light produced by the light bulb.” Record this for question 18. Tell students that changing the color given off by the light bulb does not change the amount of energy needed for the bulb therefore, we do not
need to consider this when looking at the bulb. Circle “No” for question 18 while students circle “No” in their notebook.

Turn the class notebook to page 30 and instruct students to do the same in their notebook. Make sure the extension cord with power strip plug in (the lamp should be unplugged at this time), hanging lightbulb holder, multimeter with probes, and amp meter are all nearby. Tell students, “Each of these lightbulbs has the same number of lumens. We are going to test if they produce different amounts of power. First, we will measure the voltage. All lightbulbs plug into wall outlets and our wall outlets give off the same amount of voltage. We can measure the voltage that comes out of plugs.” (Note: This step could be dangerous for students so make sure to tell them that they should under no circumstances try this at home.) Turn the multimeter to the 200 V~ setting and place the multimeter under the document camera. Place the black lead into one of –holes in one of the socket’s on the power strip and place the red lead into the partner hole on the power strip. See picture below for example. (Note: it does not matter which lead goes into which hole because the current is alternating.) Have students read the voltage produced from the socket, then remove the probes. Ask students, “What is the voltage emitted in sockets?” Students should reply, “120 V.” Tell students, “LEDs and incandescent/halogen bulbs will operate directly at 120 V.” Fill this in the voltage box in the table under the LED and incandescent/halogen lightbulb.

Take out the picture packet, open it to page 8, and place it under the document camera. Tell students, “Compact fluorescent lightbulbs are a little different. They need a voltage smaller than the standard 120 V to operate. In order to do this, they make use of a ballast inside the base of the bulb. This ballast scales the voltage to a smaller number.” Point to the picture of the CFL on the picture packet page. Show students where the bulky base of the bulb is and tell them, “This is where the ballast is housed in the bulb. Typically, 550 lumen bulbs (like the one we are using) operate at ~65% of the standards wall outlet voltage. Knowing our operating percentage and our standard outlet voltage, we can determine the operating voltage of the CFL. To do this, we must modify our percent formula.” Direct students’ attention to the percent formula we have used for this module. Ask students, “What is the minimum value of the possible voltage?” Students should reply, “0 V.” Ask students, “What is the maximum value of voltage that can run through a wall outlet?” Students should reply, “120 V.” Ask students, “What is the range of values?” Students should reply, “120.” If students are struggling with determining the range, write the formula in the margins of the picture packet for them. Ask students, “At what percent does this CFL operate?” Students should reply, “65%.” Plug all of these numbers into the formula, then ask students, “What variable are we missing in this equation?” Students should reply, “We are missing the value.” Ask students, “What does the value represent in this equation?” Students should reply, “The value represents the operating voltage of the CFL.” Tell students, “We need to use algebra to rearrange this equation to solve for the value.” Complete the algebra with the students on the picture packet to determine the formula for the operating voltage of the CFL (students do not need to write any of this in their
notebooks). Ask students to plug the values into a calculator while you do the same, and check answers. You should calculate a voltage of 78 V. Record this in the voltage in the box on the table under the CFL. See the picture packet page below for a full breakdown of the algebra.

![Voltage of a CFL](image)

**Note:** The ballast adjusts the voltage so that the same amount of light is consistently given off by the bulb. Some of you may remember that when the first CFL came out, you turned them on and they were very dim and it took ~ five minutes for them to reach their full brightness. The ballasts now adjust the voltage up when the light turns on so that the bulb does not have a warm-up time. Once the bulb is “warm” the voltage for 550 lumen bulbs is (~65% of the wall voltage. For simplification purposes, this will not be brought up with students. If you are using a different lightbulb, you will have to change the scaling percentage. To do this, take the known power for the lightbulb (in this case, 9W) and divide by the current reading from the amp meter (in this case, 0.115 A) and turn it into a percentage.

Next, tell students, “Now we have to determine if the current produced by each lightbulb is different. To do this, we will use a device called an amp meter.” Place the amp meter under the document camera and turn it on to the 2A setting. Tell students, “I will plug in each lightbulb to the socket and clamp the amp meter around the wire. The amp meter will then read the current to 3 decimal places.” Screw the LED bulb into the socket and turn it on. Tell students, “In our experiments, we measured the current in milliamps. In this experiment, we will measure current in amps. This is because we are working with larger currents now, so we need a unit larger than milliamps.” Clamp the amp meter around the wire and have the students read the current to 3 decimal places. See picture below for example. Record the current in the current box under the LED lightbulb. Tell students, “Amps are abbreviated as capital ‘A.’”

**Note:** If you clamp around both wires you will get a current reading of 0. This is because one wire has electrons flowing in a forward direction and the other wire has electrons flowing in a backwards direction.
which causes the net current to read as 0 A. Once split, it does not matter which wire you choose to clamp the amp meter around.

Repeat this process for the CFL and halogen bulbs. The currents for each bulb should be about 0.064 A, 0.115 A, and 0.326 A respectively.

<table>
<thead>
<tr>
<th>Type of lightbulb</th>
<th>LED</th>
<th>CFL</th>
<th>Incandescent/halogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>120V</td>
<td>78V</td>
<td>120V</td>
</tr>
<tr>
<td>Current</td>
<td>0.064 A</td>
<td>0.115 A</td>
<td>0.326 A</td>
</tr>
<tr>
<td>Power</td>
<td>7.3 W</td>
<td>9.0 W</td>
<td>39.1 W</td>
</tr>
</tbody>
</table>

Tell students, “In our experiments, we calculated power in milliwatts. In this experiment, we will calculate power in watts, which is abbreviated as capital ‘W,’ since we are working with larger amounts of power.” Have students use the calculator to calculate the power produced by each bulb and write their answers in the table while you do the same in the class notebook. Have students check their answers with yours.

Once the class agrees on the power produced by each lightbulb, ask students, “Based on the information in the table, which lightbulb is ‘best,’ and why?” Possible student response: The LED bulb is best, because it uses less power to run. Fill this in for question 19.

Tell students, “In order to obtain all of this information without running an experiment, like we did, we can use the packaging of each lightbulb to help us compare and determine which bulb is ‘best.’” Direct students’ attention to the 3 Lighting Facts pictures on page 30. Tell students, “The lighting facts can be found on the back of each lightbulb package. It tells us the specifications of each bulb. The first fact sheet is for the LED, the second is for the CFL, and the third is for the incandescent/halogen.” Direct students’ attention to the “Energy Used” section of the figure and tell them, “The lighting facts tells us the expected amount of energy used by each bulb. How do they compare with the energy we calculated in our experiment?” Possible student response: all bulbs produce almost exactly the same calculated and expected values for energy.
Ask students, “What did we decided was important to keep them same between the lightbulbs in our experiment?” Students should reply, “The number of lumens.” Ask students, “How many lumens were in these three lightbulbs, and where did you find that information?” Possible student response: the brightness on the lighting facts tells us they all have 550 lumens. Ask students, “What did we decided was not important to consider when comparing lightbulbs?” Students should reply, “The temperature/color of the lightbulb.” Ask students, “Where do you see that information represented on the figure?” Possible student response: the light appearance. If students struggle, tell them that Kelvin is a measurement of temperature similar to Celsius or Fahrenheit. Since the scale runs from “Warm” to “Cool” light, ask students, “Do higher temperature readings produce warmer or cooler light, and how do you know?” Possible student response: higher temperatures produce cooler light because 5,000 K is a higher temp and closer to “cool” on the scale while 2,800 K is a lower temp and closer to “warm” on the scale. Explain to students, “The reason for this is because the sun is extremely hot, and thus sunlight is referred to as ‘natural light’ or ‘white light’. So, lightbulbs with higher temperatures will produce what looks like white light. This is referred to as ‘cooler’ tones of light. Lights with lower temperatures will produce warmer tones and will appear more yellow.”

Ask students, “What does the life of the lightbulb tell us?” Possible student response: how long the bulb will last before burning out. Record this for question 20. Ask students, “Which of the lightbulbs has the longest and shortest life?” Students should reply, “The LED has the longest life (10 years) and the incandescent/halogen has the shortest life (2.3 years).” Make sure to point out to students that these lifetimes are based on a three hour per day usage. Next, ask students, “What does the estimated yearly energy cost of the lightbulb tell us?” Possible student response: it tells us about how much it costs to run the lightbulb for three hours per day for one year. Record this for question 20. Ask students, “Which of the lightbulbs costs the least and the most amount of money to run for one year?” Students should respond, “The LED costs the least and the incandescent/halogen costs the most.” Ask students, “Based on all of the information we’ve looked at, which lightbulb is ‘best’ and why?” Possible student response: the LED bulb is “best” because it uses the least power to work (7.7 W), it lasts the longest (10 years), and it costs the least amount of money to run ($0.84).

Only do this section if there is time: Ask students, “What other information is given about the CFL lighting facts that does not appear on the LED or incandescent/halogen figures?” Possible student response: The CFL lighting facts says that the bulb contains mercury. Inform students that mercury is a very toxic gas that can fatally harm people if inhaled. If a CFL bulb were to break open, mercury gas would leak out and could harm the people in the room. Additionally, disposing of these lightbulbs is dangerous because of the hazardous material inside. If these lightbulbs are not disposed of properly, it is possible that the mercury could be absorbed into some local body of water and our entire water system would be contaminated. This is another reason why LED bulbs are “better” than CFL bulbs.

Tell students that they have taught you a lot about energy and solar panels. You have learned that different devices require different powers. Solar panels can be used to generate this power and if you knowing how the solar panel is set up you can predict the power it will produce. In addition, by making
wise decisions about the lightbulbs that we use we can lower are carbon footprint. Tell students that we will be back to do another module later in the year with then about thermal transfer in chemical reactions.

Clean-Up:

Collect calculators, put the covers back on, and place them back into the calculator box. Unplug the extension cord/power strip and free hanging lightbulb holder and put the extension cord, power strip and lamp back into the bag. Place the green and white LED cups, lightbulbs, amp meter, multimeter and probes back into the Tie of Standards materials box. Take apart the solar panel set up and place the rest of the materials in the lead box. Collect the teacher’s lab coat and bring all materials back to UCSB.

Extra Practice Solutions:
6. a) Annotate the following table:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Amount (lbs)</td>
<td>2,500</td>
<td>3,500</td>
<td>4,500</td>
</tr>
<tr>
<td>Number of Generators</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Power Output (MW)</td>
<td>43 MW</td>
<td>43 MW</td>
<td>43 MW</td>
</tr>
</tbody>
</table>

Power Output Measurements:
- Trial 1: All around plant is brown
- Trial 2: All around plant is brown
- Trial 3: All around plant is brown

b) Can this group make a conclusion? NO I DON'T KNOW

c) Annotate the following possible conclusion:

Possible Conclusions:
- When the water amount was 600%, the power output was 50 MW, and when the water amount was 400%, the power output was 40 MW. Therefore, the water amount is the power plant, the power output is increases.

d) Is this a correct conclusion for the results table? NO I DON'T KNOW

Directions: Some engineers wanted to know how changing the percentage of water amount would affect the power produced by the power plant. They did 8 experiments, using a different coal amount each time, and plotted each of their data on a graph. Answer questions using the graph below.

5. a) Annotate the graph:

b) Plot the data points on the chart below on the graph using circles (●) as markers.

<table>
<thead>
<tr>
<th>Coal Amount (lbs)</th>
<th>Power Output (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>80</td>
<td>75</td>
</tr>
<tr>
<td>100</td>
<td>50</td>
</tr>
</tbody>
</table>

- As percent water amount increases, power output decreases.
- What will the power output be if a power plant uses 3,000 lbs of coal and 2% water amount?
  ~ 50 MW

7. a) What will the power output be if a power plant uses 3,000 lbs of coal and 5% water amount?
  ~ 50 MW

CROSSWORD PUZZLE

Directions: Fill out the following crossword puzzle using the clues below.

Clues:

Across:
1. A set of steps to conduct an experiment.
2. A scientific practice in which data is examined for patterns and trends.
3. Solar power, wind power, and hydroelectric power are all examples of _______.
4. A measure of the energy of a system over time.
5. A method for a specific task.
6. An example of an energy efficient light bulb.
7. Used to compare a portion of a system to a whole system.
8. If all data points are increasing, there is a _______.
9. Energy that is not used is called _______.
10. A device that can convert heat energy, light energy, or electrical energy into mechanical energy.
11. A measure of the force that makes electricity move.

Down:
1. Reduces the water amount and increases the power output.
2. The percentage of decreases in water amount.
3. Increases the water amount and decreases the power output.
4. The amount of water used in the experiment.
5. Reduces the water amount and decreases the power output.