Module 2: Wind Turbines

4th 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. Some 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 procedures or the procedure activity.

Activity Schedule:

There are no scheduling restrictions for this module.

- Day 1: Procedure Assessment/Technique/Observations (60 minutes)
- Day 2: Variables/Question/Materials Page/Experimental Set-Up/Procedure Activity (60 minutes)
- Day 3: Procedure Activity/Procedure (60 minutes)
- Day 4: Results Table/Experiment/Graph (60 minutes)
- Day 5: Results Summary/Poster Making (60 minutes)
- Day 6: Poster Presentations (60 minutes)
- Day 7: Procedure Assessment/Tie to Standards/Content Assessment (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 10-11 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 two subgroups, ~five students each, to perform their experiments. Students stay in these subgroups for the rest of the module. One volunteer is assigned to help each of the groups (two subgroups). We find these groups work best when they are mixed levels and mixed language abilities.

NGSS Performance Expectation Addressed:

4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
**Common Core Mathematics Standards Addressed:**

4.NF-6 Use decimal notation for fractions with denominators 10 or 100.

4.MD-6 Measure angles in whole-number degrees using a protractor. Sketch angles of specified measure.

**Learning Objectives:**

1. Students will know that electricity is a form of energy.
2. Students will know that energy can be transferred from one form to another.
3. Students will be able to state which value of a changing variable would be most optimal for constructing a wind turbine given a data set or graph.
4. Students will be able to identify if a possible procedure step contains information about the changing variable, controls, and/or data collection.
5. Students will be able to determine if a statement could be a correct step for a procedure from a given question and experimental set-up.
6. 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 two subgroups (~five students), to perform experiments.

1. Module 1 & 2 (year 1)
   a. Classroom Teacher Leads a Group
2. Module 3 & 4 (year 2)
   a. Classroom Teacher Co-Leads the Class (an experienced SciTrek volunteer will be present to help out if needed)
      i. Classroom teacher will be responsible for leading entire class discussions (examples: procedure activity, tie to standards, etc.).
      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.
3. Any Additional Modules (year 3 and beyond)
   a. Classroom Teacher Leads the Class
      i. Classroom teacher will be responsible for leading entire class discussions (examples: procedure activity, tie to standards, etc.).
      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.

SciTrek staff will be 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 sci trekadmin@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 scitrekadmin@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 do 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.
2. Inform SciTrek staff if your class uses any method of subtraction other than what is shown below.

**During the Module:**

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 three floor spaces available for the students to perform the initial observation. Each group will need a place to plug in one fan and a ~1 ft x 3 ft floor space for the experimental set-up as well as additional space for ~ten students to sit. This ensures that students can begin the module as soon as SciTrek arrives. The desks/tables do not need to be moved into groups.

**Days 2-5:**
Have the students’ desks/tables moved into six 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 4:**
Have six floor spaces available for students to perform experiments. Each group will need to plug in one fan and a ~1 ft x 3 ft floor space for the experimental set-up as well as additional space for ~five students to sit.

Days 6 - 7:
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](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, you can do one or both of the following activities before SciTrek arrives:

1) Procedure assessment
2) Technique discussion

Day 2:
If you would like to have more time for your students to generate variables and design their experiments, you can do the first part of the procedure activity after SciTrek leaves (pages 10 and 11, student notebook).

Day 3:
If you would like to have more time for your students to write their procedures, you can do the second part of the procedure activity (pages 12 and 13, student notebook) before SciTrek arrives.

Day 4:
If you would like to have more time for your students to perform their experiments before SciTrek arrives.

Day 5:
If you would like to have more time for your students to analyze their experiments and make posters, you can do the example results summary before SciTrek arrives.

Day 6:
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 7:
If you would like more time for the tie to standards activity, you may give the procedure assessment before SciTrek arrives.

**Materials Used for this Module:**

1. KidWind Mini Wind Turbine with Blade Design kit (Vernier Part Number: A0043). This kit comes with a multimeter. To keep the wind turbine from falling apart the turbine head is hot glued to the metal shaft and the bottom plastic piece is hot glued to the wooden base and the metal shaft. In addition, a $\frac{5}{16}$ in. x $\frac{1}{2}$ in. washer (Home Depot Part Number: 804800) is super glued to the front of the turbine head to keep the motor from pulling out when the hub is removed. In order to measure current, a 100 Ω resister (RadioShack Part Number: 2710005) is soldered to one of the wires coming from the wind turbine. Using this resister you should get current values between 0-12 mA. To make a better connection between the
multimeter and the wires from the wind turbine, the leads on the multimeter are cut off and alligator clips (Radio Shack Part Number: 2700380) are soldered on in their place. When plugging the leads into the multimeter, the plugs are put in backwards (red into the COM and black into VΩMA). This is done because if blades are put at an angle between 0˚ and 90˚ the current read out is positive when the leads are backwards. For angles between 90˚ and 180˚ the wind turbine spins in the opposite direction and the current read out is negative. See pictures below for the modifications that are made to the KidWind Mini Wind Turbine with Blade Design kit.

2. KidWind Wind Turbine Hub (10 pack) (Vernier Part Number: H0043). Extra hubs are needed so that the hubs can be given to students with dowels already in them. This is done because inserting and tightening dowels into the hubs is challenging for students and hubs can get stripped if tightened too much. The dowels are inserted 1 cm into the hubs and then are labeled every 0.5 cm from 0 cm to 6 cm. In addition, 2 in of masking tape is wrapped around the end of the dowel to allow the straw to fit tighter when inserted over the dowel. See picture below.

3. Wind turbine blades are printed onto cardstock and then laminated. The cardboard blades that are used for the initial observation are cut from the cardboard that comes with the wind turbine kit. Marks are then drawn on the cardboard blades so that they look like the cardstock blades and then these blades are
laminated. For the template for the blades contact scitrekadmin@chem.ucsb.edu. After lamination, straws (Smart and Final Part Number: 8 in Fat Black Straws) are cut to 13.5 cm and hot glued to the backs of the blades. Three hot glue dots are placed in the center of the back of the blade at 1 cm, 7 cm, and 12.5 cm. A silver metallic Sharpie is used to draw a 1.5 cm line on the straw starting 2 cm from the bottom (next to the flat end of the blade) of the straw. This line is used to show students where to put the 9/16” wide mini binder clip (Office Max Number: 25014243) used to affix the blade to the dowels. See pictures below.

4. Lasko 20 in Box Fan. Many different fan types were tested and a large box fan is needed to get reliable results. (Lasko Model Number B20200)
5. $\frac{1}{8}$ in. x 1 in. Zinc-Plated Fender Washer (Home Depot Part Number: 204276365)
   Washers are super glued together to make stacks of 3, 6, 9, 12, 15, 18, 21, 24 to be used for weights. Washer stacks are labeled with black Sharpie to make it easier to identify.
6. KidWind Blade Pitch Protractor (Vernier Part Number: H0259 Fisher Part Number: S04804ND)
7. Swing Arm Protractor (OfficeMax Part Number: 20072966)
8. Maglite Mini AAA LED Flashlight (Walmart Part Number: 551779062)
9. Radiometer (Educational Innovations Part Number: RAD-100)
10. 152 cm/60 in. flexible measuring tape (ETA hand2mind Part Number: INS24)
11. Ruler (Office Depot Part Number: 21215472)
12. Masking Tape
13. Magnet lightbulb demonstration is made by taking a 2.5 in. ring that previously held ribbon on it and drilling a $\frac{1}{8}$ in. hole the middle of the side. 400 wraps (200 each side of the hole) of 30 AWG magnet wire are wrapped around the ring. Then, a 1.5 V 40 mA bulb is attached to the ends of the wire (All Electronic Corp. Part Number: LP-3) using crimp connectors. To hold the bulb in place a 1.5 in. x 1.25 in. piece of plexiglass is superglued to the ring and a $\frac{1}{16}$ in. hole is drilled in the plexiglass to hold the bulb. Then, a 5 in. threaded rode (#8 -32) is inserted into the hole so that one end sticks out by 0.25 in. and the other end sticks out by 1.75 in. On the threaded rod in the middle of the ring are 4 #8-32 nuts and a 0.5 in. piece of 3/8 PVC. Nuts are tightened on either side of the PVC pipe to hold it in place. The two remaining nuts are glued in place with super glue, leaving just enough room for the rode to spin. A knob is then put on the long end of the threaded rod to make it easier to spin. Two disk neodymium magnets 1 in. x 0.25 in. are put on either side of the PVC pipe (Education Innovation Part Number: M-165).

14. Clipboard (OfficeMax Part Number: 21678980)
All printed materials used by SciTrek (student notebooks, materials page, lead picture packet, poster parts, instructions, and nametags) can be made available for use and/or editing by emailing scitrekadmin@chem.ucsb.edu.

**Day 1: Procedure Assessment/Technique/Observations**

**Schedule:**

- Introduction (SciTrek Lead) – 2 minutes
- Procedure Assessment (SciTrek Lead) – 10 minutes
- Module Introduction (SciTrek Lead) – 5 minutes
- Technique (SciTrek Lead) – 15 minutes
- Observation Discussion (SciTrek Lead) – 2 minutes
- Observations (SciTrek Volunteers) – 23 minutes
- Wrap-Up (SciTrek Lead) – 3 minutes

**Materials:**

**Volunteer Boxes:**

- (3) Volunteer Boxes:
  - □ Student nametags
  - □ (12) Student notebooks
  - □ Volunteer instructions
  - □ Picture of experimental set-up
  - □ Volunteer lab coat
  - □ (2) Pencils
  - □ (2) Wet erase markers
  - □ 152 cm measuring tape
  - □ (2) Rulers
  - □ (12) Swing arm protractors
  - □ Masking tape
  - □ Wind turbine protractor
  - □ Multimeter
  - □ Ziploc bag with example cardstock blade, cardboard blade, and stack of 3 weights

**Other Supplies:**

- □ (3) Large group notepads
- □ (35) Clipboards
- □ (4) Bags With
- □ Wind turbine hub with 3 attached dowels and cardstock blades with 3 weights
- □ Wind turbine hub with 3 attached dowels and cardboard blades with 3 weights
- □ Wind turbine base

**Lead Box:**

- □ (3) Blank nametags
- □ (3) Extra student notebooks
- □ Lead instructions
- □ Wind Turbines picture packet
- □ Picture of experimental set-up
- □ Lead lab coat
- □ (35) Procedure assessments
- □ Time card
- □ (2) Pencils
- □ (2) Wet erase markers
- □ (3) Markers (orange, green, blue)
- □ 152 cm measuring tape
- □ (2) Rulers
- □ (3) Swing arm protractors
- □ Masking tape
- □ Wind turbine protractor
- □ Multimeter
- □ Ziploc bag with example cardstock blade, cardboard blade, and stack of 3 weights
- □ Hub with one dowel
- □ Cardstock blade
**Notebook Pages and Notepad Pages:** (Note: Notebook pages are rectangular and filled out in black and notepad pages are squarer and filled out in blue.)

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**OBSERVATIONS**

**Experimental Set Up:**

On the picture below, indicate relevant dimensions of the wind turbine.

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Other aspects of the experimental set up:
- 3 blades
- Fan distance = 60 cm
- Turbine angle = 40°
- Pinionstock and lashboards blades
Set-Up:

SciTrek Lead:
If the classroom has a document camera, ask the teacher to use it for the wind farm picture (page 1, picture packet), class question (front cover, student notebook), and technique activity (pages 2 and 3, student notebook). If the classroom does not have a document camera, then tape the example poster-size notebook pages to the front board and write the class question on the board during the observation discussion.

On the board, write the three group colors (orange, blue, and green) and the name(s) of the volunteer(s) that will be working with each group.

SciTrek Volunteer:
Put your name, the teacher’s name, and your group color on the top of your group notepad.

As students are taking the procedure assessment, walk around the room and quietly place the students’ nametags, which are in your group box, on each student’s desk.

Once you have passed out the nametags, assemble the experimental set-up (shown in picture below as well as in the experimental set-up picture in your group box) on a spot on the floor where ten students can sit. Use the following steps to help you with the set-up:

1. Roll out the tape measure and set the fan and wind turbine stand 60 cm from one another so that they are facing each other. Fans cannot be placed against a wall.
2. Connect the multimeter to the wind turbine by clipping the alligator clips on the red wire to the red wire on the wind turbine and the black wire to the black wire on the wind turbine. Make sure that the red and black wires do not touch.
3. Make sure that each blade has 3 weights attached at 6 cm and that the blades are attached to the dowels on the hub at 3 cm. If the weights have come off, there is masking tape in your box.

4. Use the wind turbine protractor to ensure that the blade angles are all 40°. This is done by inserting the wind turbine protractor onto the adjustable side of the hub so that the dowel is inside the notch of the wind turbine protractor and the protractor is sitting on top of the hub. If needed, adjust the blades to be at a 40° by rotating the black straw attached to each blade. The binder clips holding the blades to the dowels do not need to be removed to do this.

5. Connect the wind turbine hub with cardstock blades (white) to the wind turbine stand.

6. Place a swing arm protractor against the turbine base (parallel to the fan). Move the swing arm so that it is pointed at 60°. Turn the turbine base so the head of the turbine (turbine angle) is pointed at 60°.

7. Place the wind turbine hub with the cardboard blades (brown), wind turbine protractor, extra cardstock blade, extra cardboard blade, stack of three weights, and rulers next to the set-up.

8. Get 11 clipboards form the clipboard box and place next to the experimental set-up.

9. Leave the multimeter and fan off.

When removing the hub from the wind turbine, always have one hand on the wind turbine with your thumb on the front washer and pull the hub off with your other hand.

Introduction:
(2 minutes – Full Class – SciTrek 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.”
If you are a teacher that is leading the class tell your students that they are going to start a long-term science investigation and you have asked some scientists from UCSB to come and help. Allow the UCSB volunteers to introduce themselves and share their majors.

**Procedure Assessment:**
*(10 minutes – Full Class – SciTrek Lead)*

As the students are taking the assessment, the volunteers should get the student nametags out of their group boxes and walk around the room locating their students. Have the volunteers quietly lay each student’s nametag on their desk. If students do not have their name on their paper remind them to do so. After volunteers have handed out the nametags they should assemble the experimental set-up.

“Before we start with the module we will determine how your ideas on procedures are developing.” Pass-out the procedure 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.

Read the question, changing variable (example: the changing variable was nutrient amount), and controls (example: the controls were plant type, liquid type, plant mass...). You do not need to read the values of the changing variable or the controls. Then, read the directions to the students. Read each of the statements and have students underline controls/circle changing variables/box data collection before circling if the statement could be an appropriate procedure step. When students are finished, collect the assessments and verify that the students’ names are on the top of the papers.

**Module Introduction:**
*(5 minutes – Full Class – SciTrek Lead)*

As soon as students complete the procedure assessment, volunteers should 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 (volunteer’s names should be written on the board next to the group color they will be working with) on the front cover of their notebook. Students will leave the subgroup number 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 SciTrek notebook. They will be placed in a group when the class gets into groups for observations and they can fill out their group color and volunteer at that point.

Show students the picture of the wind farm from on page 1 of the picture packet. Ask students, “What is shown in the picture?” By the end of the conversation make sure that students know that the picture is of wind turbines. If students use the word “windmill,” tell them that scientists and engineers call these wind turbines. Ask the students what the wind turbines are used for. Students should say that the wind turbines are large “fan like” machines that can generate electricity when they rotate. Probe the students further by asking them what electricity is used for. Students should be able to list several devices such as cell phones, TVs, and refrigerators that use electricity. Tell students that scientists can use a device called a multimeter (show the multimeter to the class) to measure the amount of electricity a wind turbine produces. Introduce the word current and explain to students that it is a way to measure electricity. Therefore, in this module we will measure the current the wind turbine produces. The multimeter will read out the amount of current in milliamps. Have the class say the words “current,” “multimeter,” and “milliamps” with you a couple of times while you are introducing them to help them get used to these words.
**Teacher note:** The term windmill is used for wind structures that are used to pump water, grind grain, or perform other tasks in which the wind energy goes directly into completing a task without being converted to electricity. The term wind turbine is used for wind structures that generate electricity.

Tell students for this module, we will be exploring how changing variables associated with the wind turbine affect the amount of electricity/current the wind turbine produces. Or more simply stated, we will explore the question “What variables affect the current a wind turbine produces?” Write this question on the front page of the example notebook under the document camera and have students copy the question onto the cover of their notebooks.

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

As soon as students write the class question on the front of their notebook, volunteers should pass out a swing arm protractor to each student.

Tell the class that during our experiments we will need to be able to describe how the blades are attached to the wind turbine hub as well as where the wind turbine is in relation to the fan (wind source). One tool that scientists use to do this is a protractor. There are many different types of protractors, and we will be using two types this module. Show the students the swing arm protractor and the wind turbine protractor. Tell students that while both protractors are used to measure angles, they are useful for different methods of measuring angles. One protractor has a swing arm, which is useful to trace along angles, and the other has an insert so it can be wrapped around a dowel to measure blade angles. Show students how the wind turbine protractor fits around the dowel on the wind turbine hub.

Tell students we will first learn how to determine the angle of two objects relative to each other using the swing arm protractor, which will help us determine the turbine angle. Have students turn to page 2 of their notebooks and place an example notebook turned to page 2 under the document camera. Review the parts of the swing arm protractor while pointing to each part on an example protractor. Tell students that the outer clear scale shows the angle measurement from 0°-180° and the inner colored scale shows the scale from 180°-0°. For this module we will only use the outer scale. The swing arm is the part of the protractor that moves and is used to determine the angle of an object in relation to another object. The angle is read off the clear side of the swing arm regardless of the scale used. The origin of the protractor is where the swing arm is attached and should be placed at the center of one of the two objects. In our experiment, we will place the origin at the turbine base when measuring the turbine angle. The baseline is where the start of the inner and outer scales meet and will be against the base of the turbine parallel to the fan. To measure an angle, the protractor is put on one object and the swing arm is pointed at the other object. A picture of these parts is shown below on the left.
Tell the students that we are now going to determine the turbine angle. For the experiment, the origin will be placed against the turbine base, parallel to the fan, and the swing arm will be pointed in the direction of the turbine head. **For this activity**, we can put the swing arm protractor on the turbine head, parallel to the fan, and point the swing arm in the direction the head is turned. As a class, complete example “A” together and confirm that the turbine angle is 135°. Then have students complete “B” through “D” on their own. Once you notice the majority of students are finished have them share out their answers to check them with the class. Tell students that it is okay if their answers differ by up to three degrees. See example notebook below. Volunteers should walk around and assist struggling students as they complete page 2. As soon as students have completed page 2, volunteers should collect the protractors.

Have the students turn to page 3 while you turn to the same page in the example notebook. Show students the example hub with one blade attached. Show students how to insert the wind turbine protractor (from the adjustable side of the hub) so that they are able to measure the blade angle and how the blade can be twisted to reach a desired blade angle. The binder clip on the back of the blade does not need to be removed to do this. Next, remove the binder clip and show the students that the blade can be moved up and down on the dowel, and there are markings on the dowel that show where the blade is placed.

Tell students we are now going to learn how to read the wind turbine protractor to determine the blade angle. Point to the picture of the wind turbine protractor in the upper right hand corner of page 3. Have students label where 0°, 90°, and 180° would be on that protractor. If needed, bring out the swing arm protractor and use it to help the students determine the locations. Then show students that all of the numbers between 90° and 180° have minus signs in front of them. Tell students that sometimes protractors show the number that they need to subtract from 180° instead of the exact angle. To help students understand, circle -40° on the wind turbine protractor picture labeled with 0°, 90°, and 180°. Ask students what we should do if we wanted to find the real angle. Students should say that we would need to take 180° and subtract 40°. Show the appropriate form of subtraction as dictated by the classroom teacher in the margins of the notebook to determine that the angle would be 140°. Tell students that
when we talk about blade angles larger than 90° during this module we will only refer to them as numbers without the minus signs, therefore, we need to be comfortable with determining these values.

Tell the students we are now going to draw in where a blade would be at a given angle on a wind turbine protractor. As a class, complete example “A.” Tell students that you will put your finger on the 0° mark and trace it around the protractor and they should tell you to stop when you are at the correct angle. If students do not tell you to stop and you pass the correct angle, go back to the 0° mark and start again. Once students have found the correct angle draw a line at that angle representing the blade. Next complete example “B” together. Repeat the process of having students tell you when your finger is at the appropriate angle, and when an agreement is reached, draw a line at that angle representing the blade. Then solve for the real angle by writing 20° next to the minus sign under 180° and performing the subtraction. Students should determine this angle to be 160°. Circle this answer.

Have students complete example “C” on their own. As students are working, volunteers should walk around and help students that are struggling. Once the majority of students are finished, go over the answer. Repeat the process of having students tell you when your finger is at the appropriate angle and when an agreement is reached draw a line at that angle representing the blade. Then solve for the real angle for -70° by writing 70° next to the minus sign under 180° and performing the subtraction. Students should determine the angle is 110°. Circle this answer.

As a group, complete example “D.” Ask students what number you would look for on the wind turbine protractor if you wanted the blade angle at 150°. Remind students that for angles over 90°, the number shown on the wind turbine protractor is the number you would need to subtract from 180° to get the angle. Ask students if the angle was 150°, what you would need to subtract from 180° to find the angle on this protractor. Make sure by the end of the conversation they know that they would need to subtract 30° from 180°, therefore, they should look for -30° on the wind turbine protractor. Write 30° next to the minus sign under 180° and circle -30° in the example notebook. Once they have determined the angle, have them try to draw the blade angle at the appropriate position on the protractor on their own. Once the majority of students have completed this, repeat the process of having students tell you when your finger is at the appropriate angle. When an agreement is reached, draw a line at the angle representing the blade.
Tell students that now they know how to use a protractor to measure turbine and blade angles, and they will be able to use these skills in the next activity. Tell students that they are going to make some observations of a wind turbine system, but before we do this, we need to understand observations.

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

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.

“In this experiment we are going to make observations of wind turbines made with two different blade materials.” In addition, tell the students that they will measure the current that the wind turbine produces in milliamps. The more current a wind turbine produces, the more electricity the wind turbine produces. Put an example multimeter under the document camera (shown below) and tell students that in order to read the current, they will turn the dial to the setting that is boxed in red.
Tell the class they will now get in their groups and make observations. To determine their group, they will need to look at the color of their nametag (orange, blue, or green). 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:**
*(23 minutes – Groups – SciTrek Volunteers)*

Once the students come over to your group, have them sit in boy/girl fashion, making sure that no students are sitting behind the fan. Verify the floor is set-up as described in the set-up section. Pass-out clipboards to each student and then have them turn to page 4 of their notebook.

As a group, have the students come up with ~ten observations (~one observation per student) about the experimental set-up before you turn on the fan. This should take you no longer than 15 minutes. Observations should be recorded on the picture of the wind turbine or under the “other aspects of the experimental set-up” section in the group notepad and then copied into student notebooks. Observations about the experimental set-up can be recorded in bullet points. The two extra blades (one cardstock and one cardboard) and extra weights are for students to observe and measure. After you have come up with observations as a group, see if each person can generate 1 or 2 unique observations on their own. Make sure to record the following observations about the experimental set-up: dowel placement (3 cm), blade angle (40°), number of weights (3), weight placement (6 cm), turbine angle (60°), and fan distance (60 cm). See example notebook below for possible experimental set-up observations; feel free to deviate from the example.
Have students turn to page 5 of their notebooks while you turn to page 2 on the group notepad. Make sure that no students are sitting behind the fan and that nothing is touching the fan. First turn on the multimeter, and then turn the fan on high. Once the wind turbine has gotten up to speed, have the students watch the current reading for ~15 seconds and then record the current (in mA) that showed up most often. Once students have recorded observations for the cardstock blades, remove that hub from the wind turbine base and replace it with the hub with cardboard blades. When removing the hub from the wind turbine, always have one hand on the wind turbine with your thumb on the front washer and pull the hub off with your other hand. Have students measure and record the current produced when using the cardboard blades.

Once students have recorded the current measurements for both blade materials have them generate a list of similarities and differences between the two blade materials. Record these in the group notepad as students copy them into their notebooks.

If there is extra time, have the students generate a list of other observations about the wind turbine system and record these under “other observations” in their notebook. If there is not extra time leave this section blank.

An example group notepad/student notebook is shown below; feel free to deviate from the example.
Wrap-Up:
(3 minutes – Full Class – SciTrek Lead)

Have each group share one of the observations with the rest of the class and describe the experiment that they just carried out, as well as what they learned. By the end of the conversation, make sure that they understand that the blade material has only a slight effect on the amount of current produced by the wind turbine, because the cardboard blades gave a slightly larger current than the cardstock blades.

**Teacher Note:** Some groups may find that the two blade materials produced a similar amount of current. The blade materials used in this experiment were similar in many ways, causing the current produced to be close to each other. Students will be given the opportunity to explore other blade materials in the class experiment. This will also allow students to discuss what happens when we collect more data.

Tell the students that the next time we meet they will design an experiment to answer the question, “What variables affect the current a wind turbine produces?”

Clean-Up:

Before you leave, have students attach their nametags to their notebooks and place them in the group box. Turn the multimeter off. Put all of the materials into your group box, except the wind turbine base, hubs with blades, and fan. Bring all materials back to UCSB. In addition, put your lab coat back into your group box. If you would like to divide your group (~ten students) into two subgroups, you can do this by writing a “1” or “2” on the top of each student’s notebook to designate their subgroup. Make sure that the subgroups are made up of mixed gender and mixed ability students.
Day 2: Variables/Question/Materials Page/Experimental Set-Up/Procedure Activity

Schedule:

Introduction (SciTrek Lead) – 5 minutes
Variables (SciTrek Volunteers) - 14 minutes
Question and Experimental Set-Up Discussion (SciTrek Lead) – 10 minutes
Question (SciTrek Volunteers) – 5 minutes
Materials Page (SciTrek Volunteers) – 5 minutes
Experimental Set-Up (SciTrek Volunteers) – 5 minutes
Procedure Activity (SciTrek Lead) – 14 minutes
Wrap-Up (SciTrek Lead) – 2 minutes

Materials:

(3) Volunteer Boxes:
- ☐ Student nametags
- ☐ Student notebooks
- ☐ Volunteer instructions
- ☐ Volunteer lab coat
- ☐ (2) Materials pages (group color & number indicated)
- ☐ (2) Red pens
- ☐ (2) Wet erase markers
- ☐ (2) Pencils
- ☐ Notepad

Other Supplies:
- ☐ (3) Large group notepads

Lead Box:
- ☐ (3) Blank nametags
- ☐ Lead lab coat
- ☐ (2) Red pens
- ☐ (3) Extra student notebooks
- ☐ (3) Materials pages
- ☐ (2) Wet erase markers
- ☐ Time card
- ☐ (2) Pencils
- ☐ (3) Markers (orange, green, blue)
- ☐ Notepad
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.
3. When you start the fan, the wind turbine must be still and you may not push it.
4. When recording currents, start the wind turbine going up to speed and then watch the
   multimeter for approximately 10 s. Record the number you see most often.

Changing Variable (Independent Variable): Blade angle

Discuss with your group how you think your changing variable will affect the wind turbine.

QUESTION

Question our group will investigate:

• If we change the __________ variable (independent variable)
  what will happen to the ________ variable (dependent variable)

produces __________

SciTrek Member Approval

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

SciTrek Lead:
If the classroom has a document camera, ask the teacher to use it to show the day 1 experimental set-up picture (page 2, picture packet), question (page 7, student notebook), lead materials page (page 3, picture packet), experimental set-up (page 4, picture packet), and procedure activity (page 10, student notebook). If the classroom does not have a document camera, then tape the example poster-size notebook pages to the front board.

SciTrek Volunteer:
Set out student notebooks to allow you to talk to both subgroups at the same time during the variable discussion, and that allows students in the same subgroup to work together.

- 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 two materials pages, each filled out with a subgroup number (1 or 2) 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 and experimental set-up (pages 7 and 8).

Introduction:
(5 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
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 they did during the last meeting with SciTrek, and show them the picture of the day 1 experimental set-up picture (page 2, picture packet) to help remind them. They should reply that they did an experiment in which they changed the blade material (cardstock and cardboard) and measured the current a wind turbine produced. They learned that the cardboard blades produced slightly higher current than the cardstock blades. Review the terms: wind turbine, multimeter, current, and milliamp. Ask the class if they remember the class question they will investigate. They should reply, “What variables affect the current a wind turbine produces?”

Ask the students the following questions:

What does the word “variable” mean to a scientist?  
(variables are parts of the experiment that you can change)

What was the changing variable in the experiment that we did on the last SciTrek visit?  
(blade material)

Do you think that there are other variables that will affect the current produced by the wind turbine?  
(multiple variables might affect the current produced by the wind turbine)

Explain that this is why we will need to work as a class to answer the class question: “What variables affect the current a wind turbine produces?”

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 to give you a variable that they think might affect the amount of current generated by the wind turbine, 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 current a wind turbine produces. 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.

Example:  
Variable: number of blades

Why might this variable affect the current that the wind turbine produces? A different number of blades will cause the wind turbine to spin at a different speed and will change the amount of current produced.

How would you test this variable? Do several trials in which different numbers of blades are attached to the hub and measure the current of each trial.

Prediction: More blades will generate more current.

If needed, tell students they will now get into groups and generate more variables and analyze them.

**Variables:**

*14 minutes – Groups – SciTrek Volunteers*

As a group, generate a variable and make a prediction about how it will affect the current that the wind turbine produces. Encourage and challenge students to explain why they think their prediction is correct and how this variable will affect the current produced by the wind turbine. Repeat this process three more times, record these ideas on the group notepad, and have students copy it into their notebooks. If students have different predictions, they can write their own predictions in their notebooks. Next, students will individually generate at least one additional variable, make a prediction about how different values of this variable will affect the current produced by wind turbines, 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 current produced by wind turbines during the group discussion.

**Question and Experimental Set-Up Discussion:**
(10 minutes – Full Class – SciTrek Lead)

Have one student from each group share a variable that they generated and how they think it will affect the current the wind turbine produces. Make sure that students tell you their predictions about how different values of that variable will affect the current. Challenge students to justify their thinking and explore with them how this might help them design an experiment to answer the class question. For example, if a student’s variable was blade angle and they predicted that the larger the blade angle, the larger the current, ask the student why they predicted this. One possible answer could be: if the blade angle was 0° the wind turbine would not produce any current because the blades are flat, but as the blade angle is increased more current would be produced. Probe the students deeper by asking them questions such as: if you designed an experiment to test this, do you think it would be easier or harder to see if this variable affected the current produced by the wind turbine if you had blade angles that were close together? Students should respond that it would be harder to see the effects of the variable if the blade angles were close together. Therefore, they should choose values that are far apart for their experiment.

Tell students that one way scientists answer questions is by performing experiments; today they will design an experiment to help answer the class question. Since we have decided that there are multiple variables that could affect the current the wind turbine produces, each group is going to generate a smaller question about one changing variable to investigate. Once we put all the groups’ research together, we should be able to answer the class question.

Groups will first generate a question based on the changing variable that they plan to explore. They will then fill out their materials page, which will allow them to determine their experimental set-up. 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.
3. When you start the fan, the wind turbine must be still and you may not push it.
4. When recording currents, wait until the wind turbine gets up to speed. Then watch the multimeter for approximately 15 seconds. Record the number you see most often.

Tell students we are now going to generate a class question/experimental set-up together and that you will write it in an example 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 class question/experimental set-up in their notebooks.

Tell students for the class experiment we will do an expanded version of the initial observation and therefore, we will explore how changing blade material will affect the current the wind turbine produces.

Record blade material for the changing variable in the example notebook (page 7) under the document camera. Have students tell you if/how they think changing blade material will affect the current produced by the wind turbine (example answer: the thicker blade material produced slightly more current, so as blade materials become thicker they will produce more current).

Show students how to insert the changing variable and what they plan to measure/observe into the question frame to find the question that will be investigated: If we change the blade material, what will happen to the current the wind turbine produces? 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 a materials page for determining the values of their changing variable and controls. Ask students if
they know how scientists define controls. 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 blade angle was 30° for all of the trials, then one of their controls would be blade angle. These controls and control values can be different than the original experiment that they conducted on day one, but must remain constant throughout all the trials that they do for this experiment.

Show students the lead materials page (page 3, picture packet) and read the first step (Go through the bolded words and circle if it is a changing variable and underline if it is a control.) Go through the bolded words and have students identify if you should underline or circle them. Read steps 2 and 3 on the materials page (For variables that are controls, select 1 underlined value. For the variable that is the changing variable, select 4 values and write the trial letter next to each value.) Read the general materials to students and ask them if they need each one, and check the box when they say yes. Go through the remaining items on the materials page. If a variable is a control, then choose a single value, such as the original value, example: 3 weights for number of weights. For blade material (the changing variable), allow students to select the values. Ask students “if we want a narrow or wide range of values for blade material and why.” Guide students through selecting a wide range of values for blade material. If they choose a value contrary to their experimental design, question them on their reasoning. For example, if they said they wanted to use a wide range of blade materials and they only chose materials that did not bend, ask them if these values would allow them to best answer their question. Then allow them to change their values if needed.

Tell students that once they have completed their materials page they will fill out their experimental set-up. First, they will fill out the information on the changing variable. Ask students what the changing variable was for our class experiment and fill in the values for all of the trials on page 4 of the picture packet. Second, they will fill in information about the controls. Ask students for one of the controls for the class experiment. Show students how to record the control on the left side of the slash (example: number of blades) and the value of that control on the right side of the slash (example: 3). Have students tell you the controls and values until all of the blanks are filled. Eight of the controls and values will come from the materials page; the last control and value will not be on the materials page. One possible example is fan speed/3 (high).

Have students go through the same process to determine their question and experimental set-up. Remind them that because we are exploring blade material as a class, they will not be able to change this variable, and the only blade material they will have access to is cardstock. Therefore, they will get a slightly modified materials page. Once their group has completed their experimental set-up, they should raise their hands and get it approved by their SciTrek volunteer.

Place the question under the document camera so that students can refer back to it as they design their experiment. As groups move onto their experimental set-up, put the class experimental set-up (page 4, picture packet) under the document camera.
Question:
(5 minutes – Subgroups – SciTrek Volunteers)

Have students decide what changing variable they want to explore for their experiment. Encourage your subgroups to have different changing variables. Each group should briefly discuss how/why they think their changing variable will affect the current the wind turbine produces.

After groups have decided on their changing variable, have them fill out their question. When you sign off on their question, give them a materials page with their group color and number designated in the upper right hand corner. An example notebook is shown below.
Materials Page:
(5 minutes – Subgroups – SciTrek Volunteers)

Have subgroups underline their controls and circle the changing variable on the materials page. Then have them use the materials page to determine the values for the changing variable and controls. For the changing variable value, have students write the trial letter next to the value they select. Ask students to justify the values that they have chosen for the changing variable and controls and if these values will make it easier or harder to answer their question.

Make sure that students have only chosen controls that are underlined values on the materials page. An example of a materials page is shown in the experimental set-up section.

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

Have subgroups use their materials page to fill in their experimental set-ups on page 8 of their notebooks. When you sign off on their experimental set-up, collect the materials page and verify that it is filled out correctly and completely. Having the materials page filled out is essential for students to start their experiments during the next SciTrek visit. An example of an experimental set-up is shown below (right).
Tell students that you have heard some great experiments being designed and you are excited to see the outcomes of their experiments.

Tell students that now that they have determined their experimental set-up, they are going to need to write a procedure. But before they write their own procedures, it is necessary that they know what information a procedure contains and what information should not be included. Tell the students to turn to page 10 in their notebooks. Put an example notebook under the document camera and turn to page 10.

Ask the class, “What is a procedure?” After listening to the students’ answers make sure that the students understand that a procedure is a set of steps to conduct an experiment. Write this definition on page 10 of the example notebook for the students to copy.

Tell students that in order to write a procedure, we need to make sure that we understand what information MUST be included in procedures. Ask students what information they think should be included in a procedure. Make sure that students generate the following three items: 1) all values of the controls and the changing variable (independent variable), 2) what data will be collected (dependent variable), and 3) the steps listed in the order that they will be completed. If students are having trouble generating these ideas, have them think back to the information that they put into their question and experimental set-up. Once students have generated these ideas, have them fill in the blanks in their notebooks with the underlined words above while you fill in the values in the example notebook. Tell students to help us recognize control values, changing variable values, and data collection information in procedural steps, we will underline information about controls, circle information about changing variables, and box information about data collection. On the example notebook, underline the word controls, circle the words changing variable, and box the word data.
Tell the students that we also need to discuss items that MUST NEVER be included in a procedure. Ask students what information they think should not be included in a procedure. Make sure that students generate the following three items: 1) extra or irrelevant information, 2) opinions about the experiment, and 3) incorrect values of controls or the changing variable. Have students fill in the blanks in their notebooks with the underlined words above while you fill in the values in the example notebook.

**Teacher Note:** If students need help understanding what it means to have opinions or irrelevant information in a procedure, you can give them the following example: a scientist was designing an experiment to test which laundry detergent will have the largest reduction in the size of grass stains on cotton. Below are examples of steps containing an opinion and irrelevant information:

- Step with an Opinion: Get three brands of good smelling laundry detergent A) Tide, B) Gain, C) All.
- Step with Irrelevant Information: Put on cotton pants and play soccer in them until you get a grass stain.

Note: If there is still time, go onto page 11 of the procedure activity. This will make day 3 much easier. For an explanation of how to do this, see the procedure activity on day 3.
Wrap-Up:
(2 minutes – Full Class - SciTrek Lead)

Tell students that all of their experiments will help us answer the class question: What variables affect the current a wind turbine produces? Then tell them that next time SciTrek visits they will write their procedures.

Clean-Up:

Before you leave, have students attach their nametags to their notebooks 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: Procedure Activity/Procedure

Schedule:

Introduction (SciTrek Lead) – 3 minutes
Procedure Activity (SciTrek Lead) – 25 minutes
Procedure Discussion/Procedure (SciTrek Lead/SciTrek Volunteers) – 30 minutes
Wrap-Up (SciTrek Lead) – 2 minutes

Materials:

(3) Volunteer Boxes:
- □ Student nametags
- □ Student notebooks
- □ Volunteer instructions
- □ Volunteer lab coat
- □ (2) Pencil
- □ Notepad
- □ (2) Red pens

Lead Box:
- □ (3) Extra student notebooks
- □ Lead instructions
- □ Wind turbines picture packet
- □ Lead lab coat
- □ Time card
- □ (2) Pencils
- □ Notepad
- □ (2) Red pens
- □ Hub with one dowel
- □ Cardstock blade
- □ (2) Wet erase markers
- □ Weight (6 washers)
**SCIENTIFIC PRACTICES: Procedures**

**QUESTION**

If we change the popcorn brand what will happen to the number of kernels that pop?

**EXPERIMENTAL SET-UP**

<table>
<thead>
<tr>
<th>Changing Variable</th>
<th>Trial A</th>
<th>Trial B</th>
<th>Trial C</th>
<th>Trial D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Popcorn Brand</td>
<td>Pop Secret</td>
<td>Orville</td>
<td>Smart Balance</td>
<td>Act II</td>
</tr>
<tr>
<td>Microwave Power</td>
<td>High</td>
<td>Yellow</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
<tr>
<td>Time (Minutes)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Salt Amount (mg)</td>
<td>190</td>
<td>190</td>
<td>190</td>
<td>190</td>
</tr>
<tr>
<td>Initial Number of Kernels</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
</tbody>
</table>

**Controls:** (variables you held constant)

- Microwave Power: High
- Popcorn Color: Yellow
- Time: 3 Minutes
- Salt Amount: 190 mg
- Initial Number of Kernels: 250

**Optional Information:**

- Type of Popcorn: Pop Secret, Orville, Smart Balance, Act II

**Directions:**

Step 1: Read each statement and underline controls, circle **unchanged variable** and box information about data collection.

Step 2: Circle yes if the statement is correct and experimental set-up above, if not, circle no.

- a. Put the bag in the microwave on high for 3 minutes. **Yes**
- b. Get 200 kernels of yellow Pop Secret, Orville, Smart Balance, Act II. **No**
- c. Observe what happens. **Yes**
- d. Put 200 kernels of yellow Pop Secret, Orville, Smart Balance, Act II in bag. **Yes**
- e. Get 200 kernels of different yellow pop corn brands. **Yes**
- f. Count the number of kernels that popped in each bag. **Yes**
- g. Put the empty bag in the microwave on high for 3 minutes. **Yes**

**Underline controls, circle **unchanged variable** and box data collection.

**SCIENTIFIC PRACTICES: Procedures**

**PROCEDURE**

1. Get 3 cardboard boxes.

2. Attach 3 weights at 1 cm on the string.

3. Attach the string to hub at 1.5 cm and rotate to (A) 0°, (B) 60°, (C) 90°. Then attach hub to base.

4. Set the wind turbine 20 cm from the fan at an angle of 90°.

5. Turn fan on speed 5/medium.

6. Measure the current a wind turbine produces.

**PROCEDURE**

1. Get 200 kernels of yellow Pop Secret, Orville, Smart Balance, Act II.

2. Act II popcorn.

3. Put each bag in the microwave on high for 3 minutes.

4. Put the popcorn and 20 mg of salt into four separate bags.

5. Count the number of kernels that popped in each bag.

6. Eat the popcorn.

7. Have fun.

**PROCEDURE**

1. Get 3 cardboard boxes.

2. Attach 3 weights at 1 cm on the string.

3. Attach the string to hub at 1.5 cm and rotate to (A) 0°, (B) 60°, (C) 90°. Then attach hub to base.

4. Set the wind turbine 20 cm from the fan at an angle of 90°.

5. Turn fan on speed 5/medium.

6. Measure the current a wind turbine produces.
**Set-Up:**

**SciTrek Lead:**

If the classroom has a document camera, ask the teacher to use it for the procedure activity (pages 11-13, student notebook) and the procedure (page 9, student notebook). If the classroom does not have a document camera, then tape the example poster-sized notebook pages to the front board.

**SciTrek Volunteer:**

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 introduction have the SciTrek volunteers set out the SciTrek 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 current a wind turbine produces?” Tell students that today they are going to get to write a procedure for their experiment. Ask students what the definition of a procedure is. Students should reply that it is a set of steps to conduct an experiment. Review with students what should and should not be in a procedure. Tell students that before they work on their procedure they are going to determine if procedural steps are correct for a given experimental set-up, correct a procedure, and look at a group of scientists’ procedure and try to determine the values of the controls and changing variable, and what data they were collecting.

**Procedure Activity:**

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

If needed, have students get into their subgroups.

Have students turn to page 11 in their notebooks. Turn the example notebook to page 11 under the document camera. Tell students that we are now going to look at a group of scientists’ question and experimental set-up and we will then decide if the following seven statements would be appropriate procedural steps for those scientists’ experiment. Go over the question, changing variable, changing variable values, controls, and control values with the students.

Tell the students that the first thing that they should do when looking at a possible procedural step is identify the information within that statement. They will do this by underlining any information about controls, circling information about the changing variable, and boxing information about data collection. To practice, have students look at the question on page 11 and tell you what should be underlined, circled, or boxed. Within the question, students should circle “popcorn brand” and box “number of kernels that pop.” Once they have determined what information is in the step, they will have to check if the statement could be a possible procedural step by looking at the information in the question and
experimental set-up. If the statement could be a possible procedural step, they will circle “yes,” if not they will circle “no.” Tell students that they will now go over all of the statements together.

Below are the explanations and answers to letters a-g on page 11.

Letter a: Put the bag in the microwave on high for 3 minutes.
Correct – Step with Controls Only
What should be underlined, circled, and/or boxed?
“Bag,” “high,” and “3 minutes” should be underlined.
Are there any opinions, incorrect, or extra/irrelevant information in this statement?
No.
What is this step about?
This step is about the bag of popcorn that will be microwaved.
Is there any other information that should have been included in this step?
No.
Could this be a correct procedural step?
Yes (have students circle “yes”)

Correct – Changing Variable with Values
What should be underlined, circled, and/or boxed?
“200” and “yellow” should be underlined and “A) Pop Secret, B) Orville, C) Smart Balance, D) Act II” should be circled.
Are there any opinions, incorrect, or extra/irrelevant information in this statement?
No.
What is this step about?
This step is about gathering the different popcorn needed to complete the experiment.
Is there any other information that should have been included in this step?
No.
Could this be a correct procedural step?
Yes (have students circle “yes”)

Letter c: Observe what happens.
Incorrect – Vague Data Collection
What should be underlined, circled, and/or boxed?
“Find results” should be boxed.
Are there any opinions, incorrect, or extra/irrelevant information in this statement?
No.
What is this step about?
This step is about data collection.
Is there any other information that should have been included in this step?
Yes, this step does not include what data will be collected. Ask the students what data should be collected to answer the scientists’ question. They should say the number of kernels that pop for each type of popcorn.
Could this be a correct procedural step?
No (have students circle “no”)


Letter d: Put 200 kernels of yellow Pop Secret popcorn and 220 mg of salt in bag A. 

Correct – One Changing Variable Value Explained

What should be underlined, circled, and/or boxed?
“200,” “yellow,” and “220 mg” should be underlined and “Pop Secret” should be circled.

Are there any opinions, incorrect, or extra/irrelevant information in this statement?
No

What is this step about?
Putting the needed materials into the bag to complete the experiment.

Is there any other information that should have been included in this step?
No. Students may bring up that only one changing variable value is listed. Ask students if the rest could be listed in other steps. They should answer yes, therefore, this information does not need to be included.

Could this be a correct procedural step?
Yes (have students circle “yes”)

Letter e: Get 200 kernels of different yellow popcorn brands.

Incorrect – Changing Variable with No Values

What should be underlined, circled, and/or boxed?
“200” and “yellow” should be underlined and “popcorn brands” should be circled.

Are there any opinions, incorrect, or extra/irrelevant information in this statement?
No

What is this step about?
Gathering the popcorn that will be used in the experiment.

Is there any other information that should have been included in this step?
Yes, this step does not include the brands of popcorn that will be used. Since this information is missing, scientists who attempt to perform this experiment may use different brands from one another.

Could this be a correct procedural step?
No (have students circle “no”)

Letter f: Count the number of kernels that have popped in each bag.

Correct – Measurement

What should be underlined, circled, and/or boxed?
“Bag” should be underlined and “count the number of kernels that have popped” should be boxed.

Are there any opinions, incorrect, or extra/irrelevant information in this statement?
No

What is this step about?
This step is about data collection.

Is there any other information that should have been included in this step?
No. The step is about data collection and includes what data will be collected.

Could this be a correct procedural step?
Yes (have students circle “yes”)

Letter g: Put the tasty popcorn in the microwave on high for 3 minutes.

Incorrect – Opinion during Experiment

What should be underlined, circled, and/or boxed?
“High” and “3 minutes” should be underlined.

Are there any opinions, incorrect, or extra/irrelevant information in this statement?
Yes, the word tasty is an opinion and should not be included in a procedure.

Could this be a correct procedural step?
No (have the students circle “no”)


Have students open their notebook up so that they can see both pages 11 and 12 as seen in the picture below. Turn the example notebook to page 12.

Tell students, “now that we have an understanding about what steps could be correct steps for a given question and experimental set-up, we are going to correct a possible procedure for the same experiment we were working with on page 11.” Read each step of the procedure and have students tell you what you should underline/circle/box (controls/changing variable/data collection) for each step (shown below). Ask students what needs to be included for a procedure to be complete. Students may answer any of the following listed in bold below. Cover each of the following points as they are brought up, making sure to cover all of them by the end of the conversation.
A complete procedure must have all values of the controls and the changing variable.
Ask students if all controls are listed in the procedure. Go through the list of controls and put a check by them on the experimental set-up as students identify them in the procedure. Students should notice that one of the controls, time, is not included. Ask students what step this should be included in. They should respond step 2. Have students use a caret to write in 3 minutes after “on high” in step 2 so that it reads: Put each bag in the microwave on high for 3 minutes.

A complete procedure must have what data will be collected (measurements/observations).
Ask students if the data that will be collected is listed in the procedure. Students should say yes, the data that will be collected is listed in step 4. Students should notice that all of the information needed in step 4 is present, and that this aspect of the procedure is complete.

A complete procedure must have the steps listed in the order that they will be completed.
Ask students if the steps are listed in the correct order. Go through the procedural steps once more and the students should notice that steps 2 and 3 are listed in the incorrect order. Draw a double sided arrow to indicate that steps 2 and 3 should be switched with one another.

A complete procedure must never have extra or irrelevant information.
Ask students if there is any extra or irrelevant information about the experiment in this procedure. Students should notice that eating the popcorn does not help the scientist answer their original question, so this step is irrelevant. Have students cross out this step.

A complete procedure must never have opinions about the experiment.
Ask students if any opinions are listed in the procedure. Students should notice that step 6, “Have fun,” is an opinion. Students should say that not every scientist who performs this experiment will think that popping different brands of popcorn is fun, therefore, this is an opinion. Because opinions cannot be tested, this step is incorrect. Have students cross out this step.

A complete procedure must never have incorrect values of the controls or the changing variable.
Ask students if all controls that are listed in the procedure are correct values. Go through the list of controls and confirm that all but one of the controls is correct. Students should identify that the salt amount listed in step 3 is incorrect. Have students cross out “250 mg” and write “220 mg.”
Have students turn to page 13 in their notebooks. Turn the example notebook to page 13.

Tell students that now they will look at a procedure and try to find the control values, changing variable values, and what data was collected when we do not have a question or experimental set-up.

Read the procedure to the students. After each step, have students tell you what they think should be underlined, circled, or boxed (controls, changing variable, or data collection). The following should be underlined: “50 cm,” “metal,” “20 cm,” “30 cm,” “one”, and “drop.” The following should be circled: “A) 20 g, B) 30 g, C) 40 g.” The following should be boxed: “measure the time it takes for the balls to complete one swing.”
Procedure Discussion/Procedure:
(30 minutes – Full Class/Subgroups – SciTrek Lead/SciTrek Volunteers)

Tell students that in order to give them an example of how to write a procedure for their experiments, we will write a procedure together for the class experiment. Tell students that it is helpful to be able to see both their procedure and their experimental set-up at the same time. Have students open their notebooks to page 9 while you open the example notebook to page 9 and the picture packet to page 4 (the class experimental set-up). Place the example notebook under the document camera, but have the picture packet under it so you are able to quickly flip back and forth between the two. Ask the students what the class experimental question is. They should respond: If we change the blade material, what will happen to the current the wind turbine produces? Ask the students what needs to be included in a procedure. Make sure that students come up with the following three items: 1) all values of the controls and changing variable, 2) what data will be collected, and 3) the steps listed in the order that they will be completed.

Go over the experimental set-up (page 4, picture packet) from day 2 for the class experiment. Tell students that you will write down a step of the procedure for the class experiment, then they will write a step for their experiment. Remind students that they should NOT copy the class procedure into their notebooks.

Inform students that their hubs will come with the correct number of dowels in them; show them the example hub with one dowel from the lead box. Knowing this, ask them what they think the first step of the procedure should be about. Lead them to understand that it should be about getting the blades. Then flip to the experimental set-up (page 4, picture packet) and ask them which of the controls/changing variable should be included in this step. Put a small horizontal line next to each one they suggest (blade material and number of blades). Ask a student to put these variables into a step that you can write down. (Get 3 A) paper, B) Kleenex, C) metal, and D) Styrofoam blades.) Write the step in the class notebook, then ask students what you should underline/circle/box in the first step. The underline/circle/box the correct
information. (Get 3) a) paper, b) Kleenex, c) metal, and d) Styrofoam) blades) Tell students that in their subgroup they will now write their first step in their procedure and then underline/circle/box the correct information. Remind students that if their changing variable was number of blades they will need to include all of the blade numbers in their first step. Give students a few minutes to work in their subgroup to finish step one. While subgroups are working their volunteers should help them. If needed, subgroups can dictate the step to volunteers and they can write it on the small notepad found in their box and give it to students to copy into their notebooks.

Once students have written their first step, ask them what they think the second step in the procedure should be about. Lead them to understand that it should be about attaching the weights to the blades. Then turn to the experimental set-up (page 4, picture packet). Turn the horizontal lines, next to the variables used in step 1, into plus signs by drawing a vertical line through them. Tell the students that this indicates that they have already been used in the procedure. Ask students what the controls/changing variable should be included in this step. Put a small horizontal line next to each one they suggest (number of weights and weight placement). Ask a student to put these variables into a step that you can write down. (Attach 3 weights at 6 cm above the base of the blade.) Write the step in the class notebook, then ask students what you should underline/circle/box in the second step. Then underline/circle/box the correct information. (Attach 3 weights at 6 cm above the base of the blade.) Tell students that in their group they will now write their second step in their procedure and then underline/circle/box the correct information.

Once students have written their second step, ask them what they think the third step in the procedure should be about. Lead them to understand that it should be about attaching the blades to the hub. Then turn to the experimental set-up (page 4, picture packet). Turn the horizontal lines, next to the variables used in step 2, into plus sign. Ask students what the controls/changing variable should be included in step 3. Put a small horizontal line next to each one they suggest (blade angle and dowel placement). Ask a student to put these variables into a step that you can write down. (Attach the blades to hub at 1.5 cm and rotate the blades to 30°, then attach hub to base.) Write the step in the class notebook, then ask students what you should underline/circle/box in the third step. Then underline/circle/box the correct information. (Attach the blades to hub at 1.5 cm and rotate the blades to 30°, then attach hub to base.) Tell students that in their subgroup they will now write their third step in their procedure and then underline/circle/box the correct information.

Once students have written their third step, ask them what they think the fourth step in the procedure should be about. Lead them to understand that it should be about placing the wind turbine and the fan at the right position. Then turn to the experimental set-up (page 4, picture packet). Turn the horizontal lines, next to the variables used in step 3, into plus signs. Then ask them what the controls/changing variable should be included in this step. Put a small horizontal line next to each one they suggest (turbine angle and fan distance). Ask a student to put these variables into a step that you can write down. (Set the wind turbine 50 cm from the fan at a turbine angle of 90°.) Write the step in the class notebook, then ask students what you should underline/circle/box in the fourth step. Then underline/circle/box the correct information. (Set the wind turbine 50 cm from the fan at a turbine angle of 90°.) Tell students that in their subgroup they will now write their fourth step in their procedure and then underline/circle/box the correct information.

Once students have written their fourth step, ask them what they think the fifth step in the procedure should be about. Lead them to understand that it should be about turning the fan on. Then turn to the experimental set-up (page 4, picture packet). Turn the horizontal lines, next to the variables used in step 4, into plus signs. Then ask them what the controls/changing variable should be included in this step. Put a small horizontal line next to the one they suggest (fan speed). Ask a student to put this variable into a step that you can write down. (Turn the fan on speed 3 (high).) Write the step in the class notebook, then ask students what you should underline/circle/box in the fifth step. Then underline/circle/box the
correct information. (Turn the fan on speed 3 (high).) Tell students that because all groups will be turning the fan on speed 3, this will be the fifth step for all subgroups. Give students a couple minutes to write this in their notebook and then underline/circle/box the correct information.

Once students have written their fifth step, ask them what they think the sixth step in the procedure should be about. Lead them to understand that it should be about data collection. Ask students what they will record at the end of the experiment and have them put this into a step that you can write down. (Measure the current the wind turbine produces.) Write the step in the class notebook, then ask students what you should underline/circle/box in the sixth step (Measure the current the wind turbine produces). Tell students that because all subgroups will measure the current the wind turbine produces, this will be the sixth step for all groups. Give students a couple minutes to write this in their notebook and then underline/circle/box the correct information.

Flip back to page 4 of the picture packet. Turn the horizontal line next to the variable used in step 5 into a plus sign and ask students if all the variables were used in the procedure. They should reply yes because all of the variables have plus signs next to them. This indicates that the procedure is completed.

Below is what the class experimental set-up should look like with plus signs next to all control and changing variable values to indicate they have been included in the procedure. In addition, there is an example of a subgroup’s procedure.
If there is extra time have the groups complete the results table. For details on how to do this see Day 4.

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

Tell the students that during the next SciTrek visit they will perform their experiments and graph their results.

**Clean-Up:**

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

**Day 4: Results Table/Experiment/Graph**

**Schedule:**

- Introduction (SciTrek Lead) – 15 minutes
- Results Table (SciTrek Volunteers) – 5 minutes
- Experiment (SciTrek Volunteers) – 28 minutes
- Graph (SciTrek Volunteers) – 10 minutes
- Wrap-Up (SciTrek Lead) – 2 minutes
Materials:

(3) Volunteer Boxes:
- ☐ Student nametags
- ☐ Student notebooks
- (2) Gallon Ziploc Bags labeled group 1 and 2 each with the following:
  - ☐ Masking tape page with needed pieces of tape
  - ☐ (Number of Blades + 4) Binder clips

Materials needed based on changing variable selected.

<table>
<thead>
<tr>
<th>Changing Variable</th>
<th>Hubs</th>
<th>Blades</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Blades</td>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Blade Angle</td>
<td>2</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Dowel Placement</td>
<td></td>
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</tr>
<tr>
<td>Turbine Angle</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Fan Distance</td>
<td></td>
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<tr>
<td>Number of Weights</td>
<td>2</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Weight Placement</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Other Supplies:
- ☐ (6) Fans
- ☐ (6) Extension cords
- ☐ (35) Clipboards
- ☐ (7) Cloth bags with wind turbine base, 2 swing arm protractors, 152 cm measuring tape, and multimeter

Lead Box:
- ☐ (3) Extra student notebooks
- ☐ Lead instructions
- ☐ Wind turbines picture packet (make sure results table is filled out)
- ☐ Lead lab coat
- ☐ Time card
- ☐ (2) Pencils
- ☐ (2) Wet erase markers
- ☐ (2) 152 cm measuring tapes
- ☐ Scissors
- ☐ (2) Masking tape pages with needed pieces of tape
- ☐ (2) Swing arm protractors
- ☐ (4) Wind turbine protractors
- ☐ (2) Multimeters
- ☐ (10) Binder clips
- ☐ Ziploc bag with (16) stacks of 3 weights, (9) stacks of 6 weights and (10) cardstock blades
- ☐ (2) Hubs with 3 attached dowels
Set-Up:

SciTrek Lead:
If the classroom has a document camera, ask the teacher to use it for the results table (page 5, picture packet) and graph (page 15, 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 the 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.

Once the notebooks/nametags are passed out use the following steps to help you with the set-up:

1. Plug the fans in and set the wind turbine bases next to the fans. Make sure that the backs of the fans are not facing one another or are put up against a wall.
2. Connect the multimeter to the wind turbine by clipping the alligator clips on the red wire to the red wire on the wind turbine and clipping the black wire to the black wire on the wind turbine stand. Make sure that the red and black wires do not touch.
3. Set out the measuring tape, swing arm protractor, and five clipboards next to the wind turbine base and fan.
4. Leave the multimeter and fan off.
Introduction:  
(15 minutes – Full Class – SciTrek Lead)

If needed, while you are doing the introduction have the SciTrek volunteers set out the SciTrek 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 have been investigating?” Students should reply, “What variables affect the current a wind turbine produces?”

Tell students that today they will start their experiment to answer this question. However, before they start their experiment, they need to fill out the results table (some students might have completed this the previous session). Put the filled out results table (page 5, picture packet) under the document camera. Tell students that they first should underline controls, circle changing variables, and box information about data collection. For controls, they will just write the value in trial A and then draw an arrow through the remaining trials and for the changing variable, they will write the value in each box. Show them both of the cases on the filled out results table. Tell students that once they have filled out the results table, they will make predictions about which trial will produce the most/least current. They will write an “M” in the box of the wind turbine that they think will produce the most current and an “L” in the box of the wind turbine that they think will produce the least current. If they think that all trials will produce the same current, they will write “same” over all boxes.

Tell students that once they are finished with their results table, they can raise their hand and they will be given a bag with all of their experimental materials. Pull out the bag of example materials from the lead box. Ask students what their first procedural step was about. (Getting correct hub and number of blades.) Show students the hub with 1 blade as an example. Ask students what the second procedural step was about. (Attaching the weights to the blades.) Show them the premade weight stacks and tell them these will be found in their bag of materials. Then, show students how to attach the appropriate number of weights to the blade in the correct place. You will do this by placing the bottom of the example weight (3) on the line of the blade that corresponds to the weight placement (6 cm). Tell students that once the weight is in the correct position, they will tape the weight to the blade with the tape found on a card in their bag of materials. The tape card also has instructions on how to tape the weights. Show students the tape card. One side is marked “first” with a diagram of a vertically taped weight, and the other side is marked “second” with a diagram of a horizontally taped weight. Ask students which piece of tape they should use first. They should reply, “The tape on the side marked ‘first.’” Use one of the 7 cm pieces of masking tape (from the “first” side) to vertically tape the example weight to the blade. Be sure to wrap the tape snugly around the edges of the weight. Then use a 10 cm piece of masking tape (from the “second” side) to horizontally tape the weight to the blade, making sure that the tape is wrapped snugly around the weight and the tape goes around the back of the blade.

Ask students what their third procedural step was about. (Attaching the blades to the hub and the correct placement and angle.) Show them how to insert the straw (on the back of the blade) onto the dowel, and adjust the blade so that it is at the correct dowel placement using the markings on the dowel with the blade facing the front of the hub (the side with the knob). Place the example blade on the hub at a dowel placement of 1.5 cm and show students how to fix it to the dowel with a binder clip. The binder clip should be placed on the silver rectangle on the back of the straw. After placing the blade on the hub, remind students that they will adjust the blade angle by using the wind turbine protractor. Show them how to use the protractor by inserting it onto the front side of the hub (the side with the knob) and reminding them that if the blade angle is less than 90°, they turn the blade so that the blades pass 0°, 10°, etc. until the desired blade angle is reached. Then tell students that if the blade angle is greater than 90°, they turn the blade so that the blades pass 0°, -10°, etc. until the desired blade angle is reached. This will
result in the number side of the blade always facing the fan. Adjust the example blade to a blade angle of 30°, and tell the students that when adjusting the blade, they must keep their thumb on the binder clip and their finger on the front of the blade so it doesn’t come off.

Tell students that they will repeat this process for each blade on the hub, and then attach the hub to the wind turbine base. Then, ask them what their next procedural step was about. (Setting the wind turbine at the correct distance and angle.) Tell the students that once they have measured out the distance and figured out the angle, they need to place the turbine at the appropriate position and make sure the blades are not moving.

Ask the students what their next procedural step was about. (Turning the fan on.) They should tell you that the fan goes on speed 3/high. Remind the students that they cannot stand behind the fan while running the experiment. Then, ask them what their last procedural step was about. (Recording the current the wind turbine produces.) Ask the students what units we measure current in (milliamps), and remind them they need to include the units in their data. Tell them that they will turn on the fan and wait for the wind turbine to get up to speed (they should not push the blades to get them to spin). Then they should watch the current values for approximately 15 s and record the current (in milliamps) that they see the most often. In addition, they will record any other interesting observations. Tell them that as soon as the first hub is assembled, students should attach it to the turbine and record the current. The hub can then be disassembled so that the parts can be used for other hubs.

Tell students that when they remove a hub from the wind turbine they should always have one hand on the wind turbine with their thumb on the front washer and pull the hub off with their other hand. Demonstrate how to do this. Tell them that if they are having trouble removing or installing a hub they should ask a volunteer to help them.

**TeacherNote:** Students will have to reuse parts to make all the measurements. Below is a chart of the materials that will be given to students.

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Tell the students that you have already run the class experiment, and collected the data. Ask the students if they remember the class example question. Students should reply “If we change the blade material, what will happen to the current a wind turbine produces?” Show students where you recorded the class experimental data.

Tell the students that once they have collected their data, they will display their measurements on a graph (page 15). Show them how to make a graph using the class data, but make sure they DO NOT copy this data into their notebooks; they will graph their own data. Take out the class results table, page 5 of the picture packet, (shown below on the left), and put it under the document camera. Tell students that in order to graph, you will need to follow the checklist shown on page 15 of the notebook.

Tell students.

- Set-up your graph.
  - Write what you measured (example: current (mA)) on the y-axis (vertical).

Tell students that because your question was about the current produced by the wind turbine, you will graph current. Write current (mA) on the y-axis of the graph. Have students look at the graph and identify that each line on the graph represents 0.1 mA.

☐ Write your changing variable (example: blade angle) on the x-axis title (horizontal, bottom line).
   Ask students what the changing variable was in this experiment. Students should respond blade material. Record blade material on the x-axis title.

☐ On your results table, label your measurements from 1 to 4, with 1 being the trial with the smallest current and 4 being the trial with the largest current.

Tell students that graphs are used to see how changing variables affect the measurements. One way to make it easier to find patterns is to graph the data in increasing order. Put the class results table (page 5, picture packet) under the document camera and have students help determine the order that the trials will be graphed (B, A, D, then C) and write the appropriate number by each trial.

Plot your data in increasing order.
   Tell students that now that they have determined the order they will graph their data, they need to plot their data in increasing order. To do this, there are a few steps that they need to follow.

☐ Write each of the changing variable values (example: 0°/180°) for the trial that you labeled 1 under the first column.
   Ask students which trial was labeled 1. (Trial B) Then ask them what you should write for the first column. Write Kleenex for the first trial on the example notebook.

☐ Graph your data for that trial and write the measurement above the bar.
   Ask students what current will be graphed for trial B (0 mA). Draw a line at 0 mA and write the number value over the line.

☐ Repeat the process for the other trials.
   Ask students what the value for the changing variable is for the trial we will graph next. Write paper in the next column on the example notebook. Ask them what the current is for this trial (0.4 mA). Put your finger at zero and tell the students to tell you to stop once you reach the appropriate level. Once you have reached the level, draw the line, write the number value over the line, and quickly shade below the line. Tell students to look at how fast you filled in the chart and challenge them to fill in their graph faster than you when they graph their own data. Repeat this process for trial D and trial C.
Tell students that they will now fill out their results tables and as soon as they are done, they can start their experiments and graph their results.

**Results Table:**

*(5 minutes – Subgroups – SciTrek Volunteers)*

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

If a group is changing blade angle and have selected any angles over 90°, have them record both the real angle, as well as the angle seen on the wind turbine protractor. For example, 110° would be recorded as 110°/70°.

When students have finished, have them make predictions about how much current each wind turbine will produce in comparison to one another. Have them write an “M” in the box of the trial they think will produce the most current and “L” in the box of the trial that they think will produce the least current. They will leave two of the boxes empty. If they think all trials will produce the same current have them write “same” over all of the boxes. Try to question each group on their thought process behind their predicted currents. See example notebook in Experiment section.

**Experiment:**

*(28 minutes – Subgroups – SciTrek Volunteers)*

Once groups have completed the variables and predictions section of the results table, give them their bag of supplies for their blade design. If students are missing any of their experimental materials, the lead
box has extra materials. The lead box also has extra wind turbine protractors that you can give groups if it will help them finish making their hubs faster.

Subgroups will only be given limited materials. See the chart below to see materials that groups will be given. Therefore, as soon as groups have a hub constructed, they should use it to determine the current it will produce and then disassemble it to use the parts to make additional hubs. For subgroups changing number of blades, have them make and run the hub with the largest number of blades first and then reuse the blades for the hubs that have less blades.

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</table>

When students are ready to measure the current a hub design produces, have them find their place on the floor; ensure that no students are sitting behind the fan. Students should place the wind turbine base at the correct turbine angle and fan distance. Then have the students turn on the multimeter. Before turning on the fan to 3 (high), verify that the wind turbine blades are not moving. Students will wait for the wind turbine to get up to speed and then record the current that appears most often over the course of ~15 seconds. Students should not push the blades even if the wind turbine does not turn. To remove the hub students should put one hand on the wind turbine with their thumb on the front washer and then use the other hand to pull on the hub. If students are struggling with this, then remove the hub for them.

Subgroups changing the number of weights or weight placement will take the most time. Help these groups first.

As soon as students finish, collect the materials and return them to the group box. If your group has things under control, help other groups. Once a subgroup has finished, they can move onto graphing their results. An example of a properly filled out results table is seen below.
Graph:
(10 minutes – Subgroups – SciTrek Volunteers)

Help students fill out their graph by having them go through and complete the checklist on page 15. Be sure that students label the y-axis with current (mA) and the x-axis with their changing variable. To make it easier to see patterns, students should arrange the trials in increasing measurements as done in the example above. In this example, the trials were graphed in the following order: B, D, C, A. Once they have graphed their values, make sure that they write the values of the current on top of each column so that it is easy to discern the value. An example of a properly filled out graph is shown above on the right.

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

Tell the students that on the next SciTrek visit they will have time to analyze their data, and then create a poster to share their results with the class.

Clean-Up:

Before you leave, have students attach their nametags to their notebook sand place them in the group box. Put all materials in group box except wind turbines and fans. Bring all materials back to UCSB. In addition, put your lab coat into your group box.
Day 5: Results Summary/Poster Making

Schedule:

- Introduction (SciTrek Lead) – 10 minutes
- Results Summary (SciTrek Volunteers) – 15 minutes
- Poster Making (SciTrek Volunteers) – 30 minutes
- Wrap-Up (SciTrek Lead) – 5 minutes

Materials:

<table>
<thead>
<tr>
<th>(3) Volunteer Boxes:</th>
<th>(2) Stickers on how to present results</th>
<th>(9) Paperclips</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Student nametags</td>
<td>☐ (2) Pencils</td>
<td>☐ Highlighter</td>
</tr>
<tr>
<td>☐ Student notebooks</td>
<td>☐ Notepad</td>
<td>☐ Scissors</td>
</tr>
<tr>
<td>☐ Volunteer instructions</td>
<td></td>
<td>☐ (2) Glues</td>
</tr>
<tr>
<td>☐ Volunteer lab coat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>☐ Poster diagram</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Poster Parts Packs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>☐ Scientists’ names</td>
<td>☐ Results table</td>
<td></td>
</tr>
<tr>
<td>☐ Question</td>
<td>☐ Results graph</td>
<td></td>
</tr>
<tr>
<td>☐ Experimental set-up</td>
<td>☐ Results summary</td>
<td></td>
</tr>
<tr>
<td>☐ Procedure</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other Supplies:

- ☐ Poster paper tube

Lead Box:

- ☐ (3) Extra student notebooks
- ☐ Lead instructions
- ☐ Wind turbines picture packet
- ☐ Poster diagram
- ☐ Lead lab coat
- ☐ Time card
- ☐ (2) Stickers on how to present results
- ☐ (2) Pencils
- ☐ Notepad
- ☐ (2) Wet erase markers
- ☐ (9) Paperclips
- ☐ (2) Highlighters
- ☐ (2) Scissors
- ☐ (2) Glues
- ☐ Scotch tape
- ☐ Poster part pack (2 each color)
Set-Up:

SciTrek Lead:
If the classroom has a document camera, ask the teacher to use it for the results summary (page 16, student notebook). If the classroom does not have a document camera, then tape the example poster-size notebook pages to the front board.

Ask the classroom teacher for a place to leave the student posters in the classroom.

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:
(10 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 the class, “What is the class question that we have been investigating?” Students should reply: “What variables affect the current a wind turbine produces?” Tell students they are going to analyze their results from their experiments which will allow them to start answering the class question.

Tell students we will start by analyzing the class data together. Put the filled out results graph from the class example under the document camera (page 15, student notebook). Tell students we will now work together to try to determine which value(s) of our changing variable allow us to get the greatest current and why.

Ask students what patterns they see in the results. To help students see the patterns have them look at the two materials that gave the smallest currents (Kleenex, paper towels, or paper) and ask them what these materials have in common. If needed show students the results table (page 5, picture packet) and have them look at the “other” section under data. By the end of the conversation students should realize that materials that give the smallest current are materials that either ripped or bent when the fan was turned on. Have students look at the two materials that gave the largest currents (cardstock, Styrofoam, or metal) and ask them what these materials have in common. By the end of the conversation they should realize that these materials did not rip or bend. Ask students to look at the data for the materials that did not bend or rip and ask them what they notice. They should notice that the currents are all close to 1.9 mA.

Tell students that we now need to summarize our data and tell people what values of our changing variable give the largest currents or the trend/pattern we see in the data regarding current production. Start students out by saying “My experiment shows the blade materials that produce the largest current are...” Have students tell you what should go next and ask the class if they agree. By the end of the conversation make sure that students agree that the blade materials that give the largest current are materials that do not bend, and these materials all give approximately the same current. Ask students if we can test if the flexibility of a material affects the current produced by a wind turbine. They should say yes. Tell them that if a statement is testable then it is a claim and claims are the first part of results summaries. Write “the blade materials that produce the largest current are stiff materials” in the example notebook.

Tell students that they now need to use data to support their claim. Inform students that there are two forms of data: observations and measurements. Ask students what type of data we will use to support our claim. They should respond measurements. Ask the students what measurements we would need to back up our claim. Write the following data statement after the claim in the example notebook: “because Styrofoam and metal blades (stiff) produced ~1.9 mA and the Kleenex and paper blades (flexible) produced 0 mA and 0.4 mA.”
Tell students to think back to the original observations that we made as a class. Ask them what blade materials we used for these observations. They should say cardstock and cardboard. Ask them what we saw from our data. They should respond that the current was slightly larger for the cardboard than the cardstock. Ask them if these results are consistent with what we just saw from our class experiment. They should say yes because the cardstock blades are more flexible than the cardboard blades. Remind students that it is important for scientists to repeat their experiments to make sure that their results are consistent.

Tell students that result summaries are strongest when they allow us to make predictions. Ask students if based on our summary they can predict another material that would produce a high current (wood) and a material that would produce a small or no current (tissue paper). Ask students how much current they predict would be produced by the non-bendable material. (~1.9 mA).

Tell students that after they summarize their experimental findings they will fill in the sentence frame “I acted like a scientist when____” stating how they acted like a scientist during their SciTrek experience. Challenge students to come up with a unique answer that no one else in their group has put down.

Tell students that when engineers/scientists complete their experiments, they make posters to present their work to other engineers/scientists; therefore, we will create a poster to present to the class during the next SciTrek visit. This presentation will be their chance to tell the class what their group has discovered about the class question. Tell the students that they should write as neatly as possible on the poster parts so that the other class members can read their poster.

Tell students they will now start working with their subgroup to analyze their experimental results and then make a poster.
**Results Summary:**
*(15 minutes – Subgroups – SciTrek Volunteers)*

Have students summarize their findings. Challenge students to think about how their changing variable did or did not affect the current.

Because this is an engineering activity, students should start their results summaries with a claim focused on the value (or pattern of values) of their changing variable that produced the most current. Then, they need to follow it with “because” and a data statement using their data to back up the claim. The data from this experiment is in the form of measurements, therefore, all students should be using numerical values in their data statements.

If the values of their changing variable have an order (example: 20 cm → 40 cm → 80 cm) then that variable affects the current a wind turbine produces. If, on the other hand, there was no order for their changing variable (example 9 weights → 3 weights → 24 weights) and the difference between the currents is small, then that variable did not affect the current a wind turbine produces. If possible, try to have students generate a claim that allows them to make a prediction about something that they have not tested. An appropriate claim could be: the farther the wind source is from the turbine, the lower the current. 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. After generating a claim about the experiment, write the word “because” and follow it with supporting data (because when the fan distance was 20 cm the current was 5.4 mA and when the fan distance was 80 cm the current was 2.3 mA). The supporting data should be the two most convincing data points, typically the minimum and the maximum currents.

Results summaries are still valid, and important, if they show that the changing variable tested did not affect the current produced by the wind turbine. Even if their results summary is contrary to what you think, have students make a claim based solely on their data. An example results summary is shown below.
Before starting their poster, have students fill in the sentence frame (page 16): “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.

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

Each subgroup (four/five/six students) will make one poster of their experiment.

Pass-out the writing portions (general poster parts and “I acted like a scientist when____”) and have students write their names on them and complete them. In addition, have each student write their name on the scientists’ names part. Use the following guidelines when assigning poster parts:

<table>
<thead>
<tr>
<th>Number of Students in Subgroup</th>
<th>Poster Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Each student gets an “I acted like a scientist when____” and picture space.</td>
</tr>
<tr>
<td></td>
<td>1. Question and Experimental Set-Up</td>
</tr>
<tr>
<td></td>
<td>2. Procedure</td>
</tr>
<tr>
<td></td>
<td>3. Results Graph*</td>
</tr>
<tr>
<td></td>
<td>4. Results Summary</td>
</tr>
<tr>
<td></td>
<td>Student that finishes 1st completes the results table (not presented)</td>
</tr>
<tr>
<td>5</td>
<td>Each student gets an “I acted like a scientist when____” and picture space.</td>
</tr>
<tr>
<td></td>
<td>1. Question</td>
</tr>
<tr>
<td></td>
<td>2. Experimental Set-Up</td>
</tr>
<tr>
<td></td>
<td>3. Procedure</td>
</tr>
<tr>
<td></td>
<td>4. Results Graph*</td>
</tr>
<tr>
<td></td>
<td>5. Results Summary</td>
</tr>
<tr>
<td></td>
<td>Student that finishes 1st completes the results table (not presented)</td>
</tr>
<tr>
<td>6</td>
<td>Each student gets an “I acted like a scientist when____” and picture space.</td>
</tr>
<tr>
<td></td>
<td>1. Question</td>
</tr>
<tr>
<td></td>
<td>2. Experimental Set-Up</td>
</tr>
<tr>
<td></td>
<td>3. Procedure (Presents 1st half of procedure)</td>
</tr>
<tr>
<td></td>
<td>4. Results Table (Presents 2nd half of procedure)</td>
</tr>
<tr>
<td></td>
<td>5. Results Graph*</td>
</tr>
<tr>
<td></td>
<td>6. Results Summary</td>
</tr>
<tr>
<td></td>
<td>Procedures can be cut in half.</td>
</tr>
</tbody>
</table>

*Give the results graph to the student that is most confident in presenting.*

Once all writing sections are completed, have students draw a picture of their experiment or how they acted like a scientist.

In the students’ notebooks, highlight and number the section that they will present. The parts should be numbered as follows: 1) scientists’ names, 2) question, 3) experimental set-up, 4) procedure, 5) results graph, and 6) results summary (see example below). Students will NOT present the results table or “I acted like a scientist when____” 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.
Place the following sentence frame sticker on the bottom of the notebook page of the student that is completing the results graph (page 15).

When the ______ out for the student _______ was _______ the current was _______ mA.

changing variable value measurement

Then practice reading the four sentences with that student. For the poster below, the sentence would be:
When the **blade angle** was **0°** the current was **0 mA**. Make sure you fill in the first blank (ex: **blade angle**) for the student in the sentence frame but leave the second and third blanks (**“value”** and **“measurement”**) empty.

As soon as students have completed some of their pieces, start gluing them onto the large poster paper exactly as they are arranged in the example below. 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 each of your groups a few questions about their poster. Have them use their findings to predict the current that other wind turbines would produce that they did not perform but are related to their experiment. For instance, if the group’s results summary was, “My experiment shows that the blade angle away from 0° or 180° produces the most current because 0° and 70° both produced 0 mA, and 30° produced 4.7 mA,” ask the group to predict what current a blade angle of 45° would produce. They should be able to predict that it would be between 0 mA and 4.7 mA.

If there is additional time, tell each subgroup 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.

Wrap-Up:
(5 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 present their findings during the next SciTrek visit and that 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. Leave student posters in the classroom. Bring all materials back to UCSB. In addition, put your lab coat into your group box.
Day 6: Poster Presentations

Schedule:

- **Introduction (SciTrek Lead)** – 2 minutes
- **Practice Posters (SciTrek Volunteers)** – 10 minutes
- **Poster Presentations (SciTrek Volunteers/SciTrek Lead)** – 46 minutes
- **Wrap-Up (SciTrek Lead)** – 2 minutes

Materials:

(3) Volunteer Boxes:

- ☐ Student nametags
- ☐ Student notebooks
- ☐ Volunteer instructions
- ☐ Volunteer lab coat
- ☐ (2) Pencils
- ☐ (6) Paperclips
- ☐ Highlighter

Lead Box:

- ☐ (3) Extra student notebooks
- ☐ Lead instructions
- ☐ Wind turbines picture packet
- ☐ Lead lab coat
- ☐ Time card
- ☐ Teacher evaluation
- ☐ (2) Stickers on how to present graph
- ☐ (2) Pencils
- ☐ (2) Wet erase markers
- ☐ (9) Paperclips
- ☐ (2) Highlighters
- ☐ Scotch tape

*Student posters should already be in the classroom.

Set-Up:

**SciTrek Lead:**

If the classroom has a document camera, ask the teacher to use it for the notes on presentations (pages 6 and 7, picture packet). If the classroom does not have a document camera, then write the class question on the board, “What variables affect the current a wind turbine produces?” Leave enough room to record student findings under the question.

Organize the posters so that groups that had the same changing variable present back to back.

**SciTrek Volunteer:**

Set out the SciTrek notebooks/nametags. Today students will be sitting in their regular classroom seats during poster presentations.
Tell students that today they will present their poster to the class. Inform students that this is a common practice in engineering/science. Engineers/scientists go to conferences where they present posters about the experiments they conducted. At these presentations, other engineers/scientists give them feedback on their experiments, which allows them to return to the lab with new ideas for future experiments.

Tell the students that they will have 10 minutes to practice presenting their poster 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.

Practice Posters:
(10 minutes – Subgroups – SciTrek Volunteers)

If the posters are not already in order, the lead should organize the posters so the experiments featuring the same changing variable are presented back to back.

Have subgroups practice their poster presentation, making sure they are reading the poster parts in the correct order (scientists’ names, question, experimental set-up, procedure, results graph, and results summary). 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.
If there is extra time have the students put their notebooks away and tell each other about their experiment and what they learned.

Do not let poster practice go over 10 minutes.

**Poster Presentations:**

*(46 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 tell you, “What variables affect the current a wind turbine produces?” Tell students that during the presentations they are going to take notes. Have them turn to page 16 in their notebook while you turn to page 6 of the picture packet. Tell them that they need to record each group’s changing variable when the group says their question. In addition, they will record the values of the changing variable and the measurements when the group presents their graph.

After each presentation, students will be given the opportunity to ask scientific questions to the presenting group to help them determine if/how the variable investigated affected the current produced by the wind turbine, as well as which value of each variable would give the largest current for the smallest cost. Tell them these questions are important because they will have to summarize for you what they learned from the group so you can record it on the group notes. Therefore, their questions should focus on helping them be able to summarize the group’s findings.

Student notebooks only have room for notes on 5 presentations. Therefore, they will not take notes on their own presentation.

Explain to students that one very important thing to an engineer is to be able to build something that works well and is cost efficient. When comparing different changing variable values, students should keep in mind that if an expensive option will produce significantly higher current, it might be worth it to spend the extra money to build it, however if the more expensive option will produce the same current as a cheaper option, it is best to build the cheaper option. Therefore, before moving on to the next presentation as a class we will decide which value of the changing variable would be the “best” for a wind turbine company to use and both you and the students will circle that changing variable value in the presentation notes.

Volunteers should make sure that students are quiet and respectful when other groups are presenting. When one of your groups 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.

During the student question time, the SciTrek 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 group should answer approximately five questions (one question per student).

Below is an example of notes that the lead could have taken during the poster presentations. For examples of the student presentation notes see “Notebook Pages” above.
After all poster presentations have been given, ask the class, “What did we learn about the current produced by wind turbines?” Have them summarize the class findings. The highlights from many experiments are shown below. Do not expect students to know highlights from experiments that were not run.

- The smaller the fan distance, the larger the current.
- The closer the blade angle is to 90°, the smaller the current, unless the blade angle is 0°/180° which will give no current. When using blade angles above 90°, the wind turbine spins the opposite direction and a minus sign appears next to the current. (Note: the minus sign that appears in front of the current indicates that electricity is flowing in the opposite direction.)
- The larger the dowel placement (the farther out the blade is placed), the smaller the current.
- The number of blades does not affect the current produced as long as the blades are evenly spaced. When the blades are unevenly spaced, the wind turbine will not produce current, as in the case with one blade, or will have a harder time getting started and up to speed, as in the case with 5 blades.
- Weight placement on the blade has minimal effect on the current. (Note: if students assemble their blades perfectly they might see that the closer the weights are to the hub the higher the current, but most likely they will not be able to see this because the change in current is ~0.2 mA for the weights used.)
- The number of weights should have little effect on the current the wind turbine produces. However, what many groups find is that if there are more weights, the wind turbine produces less current. This may be because many groups make their wind turbines at slightly different blade angles or weight placements. Groups also find this pattern if they do not tape their weights down tightly enough and the weights move slightly when the turbine is spinning, causing an imbalance and a decrease in current. These differences are exaggerated when the blade becomes heavier.

When summarizing experiments, use students collected data and not what they should have found from the list above. Tell students you want to produce as much current as possible and that you need them to tell you what values of variables you should use.

- Blade Material: any material that does not bend
• Number of Blades: 2 (having 2 blades would make it cheaper than having more blades)
• Blade Angle: 10°
• Fan Distance: the wind turbine should be placed in an area with a lot of wind (for us 20 cm)
• Dowel Placement: 0.5 cm
• Number of Weights: 0 (having 0 weights would make it cheaper than having more weights)
• Weight Placement: because there are no weights, weight placement does not matter

If no one in the class did experiments on one of the variables above, then they will not know how that variable affects the current produced by the wind turbine so do not expect them to tell you which value to use. Tell students they have taught you a lot about wind turbines.

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. Remove tape from the lid of your group box and place inside. In addition, 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 7: Procedure Assessment/Tie to Standards/Content Assessment

Schedule:

Procedure Assessment (SciTrek Lead) – 15 minutes
Tie to Standards (SciTrek Lead) – 35 minutes
Content Assessment (SciTrek Lead) – 10 minutes

Materials:

Lead Box:
- (3) Extra student notebooks
- Student notebooks
- Lead instructions
- Wind turbines picture packet
- Lead lab coat
- (35) Procedure assessments
- (35) Content assessments
- Time card
- (2) Pencils
- (2) Wet erase markers
- Masking tape
Other Supplies:

- Wind turbine base
- Fan
- Extension cord
- Box of tie to standards materials (clipboard, eraser, flashlight, swing arm protractor, wind turbine protractor, 152 cm measuring tape, multimeter, wind turbine hub with 3 blades attached, Tupperware with (magnet/electricity apparatus, 2 magnets, and 3 paperclips) and radiometer)

**Notebook Pages:**

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**TIE TO STANDARDS**

1. What does the current reading tell us? Electricity is being ________ generated by the wind turbine________.

2. Electric currents are a form of ____energy________.

3. Energy ________cannot be created nor destroyed, but it can be transferred________.

4. Energy can also be stored____, such as the case of gravitational energy.

5. Forms of energy
   - electrical currents
   - sound
   - gravitational
   - light
   - motion
   - heat

6. Identify the energy transfer in the wind turbine:

   Wind → rotation → blades → rotation → electrical current

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Energy Form</th>
<th>Energy Source</th>
<th>Energy Form</th>
<th>Energy Source</th>
<th>Energy Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>Rotation</td>
<td>Blades</td>
<td>Rotation</td>
<td>Electrical</td>
<td>Current</td>
</tr>
</tbody>
</table>

7. What could the energy in the wind turbine be used for?

   - Video games / Light

8. Magnets can generate ________electricity________ if the magnet is ________moving________.

9. What are the blades turning inside the wind turbine housing?

   - Magnets

10. What type of area would you recommend that Windy Works purchase land?

    - In a windy area
Set-Up:

SciTrek Lead:

Collect the “Evaluation of the SciTrek Program by Participating Teachers” form from the teacher. If they have not filled out the form, ask them to do it during the tie to standards activity.

If the classroom has a document camera, ask the teacher to use it for the tie to standards activity (pages 18-20, student notebook) and tie to standards pictures (pages 8-11, picture packet). If the classroom does not have a document camera, then tape the example poster-size notebook pages to the front board.

Assemble the experimental set-up. Use the following steps to help you with the set-up:

1. Verify that the blades on the hub are at a **dowel placement = 0.5 cm** and a **blade angle = 10°** and then attach the hub to the wind turbine base
2. Roll out the tape measure and set the **fan distance = 60 cm**.
3. Place the base of the swing arm protractor against the wind turbine base and position the wind turbine so that the head is pointing at the fan.
4. Set the **turbine angle = 90°**
5. Connect the multimeter to the wind turbine stand making sure red and black wires do not touch. The red clamp should be connected to the red wire AFTER the resistor.
6. Leave the multimeter and fan off.

Set the radiometer on a flat surface where students will be able to see it. It is important that it is not moved once it is set down, because it takes a long time for the blades to come to rest.

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

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

“Before we start our activity today we will determine how your ideas on procedures are developing. One of the ways that we get program funding is by demonstrating the program effectiveness. Therefore, we need you to do your best on the assessment.” Pass-out the procedure 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.

Read the question, changing variable (example: the changing variable was wheel material), and controls (example: the controls were wheel circumference, vehicle mass, vehicle type...). You do not need to read the values of the changing variable or the controls. Then, read the directions to the students. Read each of the statements and have students underline controls/circle changing variables/box data collection before circling if the statement could be an appropriate procedure step.

When students are finished have them turn over their paper. Read the three attitudes towards science questions to students and have them answer them. When they are finished, collect the assessments and verify that the students’ names are on the top of the papers.

Pass-out the draw a scientist paper. Tell students to fill out their name, teacher’s name, and date on the top of the assessment. Give students exactly 4 minutes to draw a picture of a scientist. Then collect the papers from students’ verifying that their names are on the top of the papers.

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

Tell the class that you enjoyed their poster presentations the last time you were there and that today they are going to learn more about electric currents and how wind turbines work.

**Energy (15 minutes)**

Ask students what they were measuring during their experiments. Students should reply that they were measuring the current that the wind turbine produced. Ask students: “What does the current reading tell us?” They should respond that the current tells us that electricity is being generated by the wind turbine. Ask students what the amount of current tells us about the amount of electricity produced. Students should respond the larger the current the more electricity that is being produced. Have students fill in question 1 on page 18. See example below.

![TIE TO STANDARDS](image)

Ask students to give you examples of what electricity can be used for. Examples: light a light bulb, power an iPhone, run a refrigerator, etc. Ask if the things that they just mentioned, such as lighting a light bulb, take energy. Students should respond yes. Ask students where the energy came from. Students should
reply the electricity. Lead students to understand that electricity, or electric currents, are a form of energy and have them fill in question 2 on page 18.

Tell students that one of the laws of science is that energy cannot be created nor destroyed, but it can be transferred from one form to another. Then have students fill in question 3 on page 18. See example below.

Ask students what they think it means that energy cannot be created or destroyed but it can be transferred and if they can give you an example of a time they saw energy transferred. Allow a few students to share their ideas. Example: when I kick a ball, energy is transferred from me into the ball (page 8, picture packet). Ask students what happens when the ball hits a wall. Make sure by the end of the conversation that students understand that when a ball hits a wall the ball transfers its energy to the wall. Because the wall is much larger than the ball, the energy from the ball makes the wall move so little that we can’t see it.

Then tell students that we are going to explore this idea. Take out the SciTrek eraser and clipboard and ask a student to come up to the front of the class to hold the clipboard. Hold the SciTrek eraser above the clipboard and ask the class if the eraser has any energy as you hold it still. Ask a couple of students to explain their reasoning. Then, drop the eraser onto the clipboard. Ask the student who is holding the clipboard what they observed. This student should say that they felt, heard, and saw the eraser hit the clipboard. Ask the class what it must mean if the eraser was felt and heard as it hit the clipboard. Students should say that it must mean that the eraser had energy which it transferred to the clipboard when it hit it. Ask students how the eraser got the energy. Students should say that the eraser’s energy came from falling down. Next, remind them that we just learned that energy cannot be created nor destroyed, so the eraser’s energy from falling had to come from somewhere before it fell. Ask students where that energy had to come from. Students should say that the energy must have come from the height the eraser was being held at. Tell students that this is what we call gravitational energy. When an object is held at a certain height, it stores a certain amount of gravitational energy that is related to the height it is being held at as well as the mass of that object. Ask the students if they think the eraser would have more or less energy if it was held closer to the clipboard. They should respond less. Hold the eraser close to the clipboard and drop it. Ask the student holding the clipboard what they felt. Next, ask the students if the eraser would have more or less energy if it was held farther away from the clipboard. They should respond more. Hold the eraser far away from the clipboard and drop it. Ask the student holding the
clipboard to tell you if they felt the clipboard move more or less than when the eraser was held closer. They should respond more. Have students fill in question 4 on page 18. See example below.

Tell students that we have talked about two forms of energy: electrical currents and gravitational. Show students these on the list on question 5 on page 18. Ask the class if they think there are other types of energy. They should respond yes. Tell the class we will try to figure out what some of these types are and add them to our list.

Remind students that energy cannot be created nor destroyed, it can only be transferred. Ask students where the eraser’s gravitational energy transferred to. Students should be able to generate the following two sources:

**Motion:** An object, like the eraser, can transfer its energy from gravitational energy into motion energy (through falling down). The conversion between gravitational and motion energy is seen in roller coasters. All objects that are in motion have energy.

**Sound:** When the eraser hit the board it produced a sound; sound is a form of energy. Ask students if they have ever been somewhere where a loud sound was produced and they felt the sound or saw the sound cause something to move. Some examples might be loud stereos or sonic booms (caused by aircrafts going faster than the speed of sound) causing windows to vibrate. The motion of the windows is caused by the sound transferring its energy into the window.

**Light:** Ask students what would happen if a wind turbine was connected to a light bulb. They should respond that the bulb will light up. Ask students if light is a form of energy. Have the class vote yes or no. To prove that light is a form of energy point out the radiometer, making sure to not move it. Ask students if it would take energy to turn the vanes. They should respond yes. Shine a flashlight on the device. The vanes will start turning when they are illuminated with light from the flashlight. Ask students where the vanes got the energy from. Since the only thing that changed was the addition of the light, students will say the light.

Tell the students that light is indeed a form of energy. Ask students how sunburns show this. By the end of the conversation make sure students understand that light came from the sun and interacted with their skin causing energy to transfer to their skin and turn their skin red.

**Teacher Note:** How the radiometer works (not to be discussed with students): The radiometer has very few gas molecules inside of it. When light hits the vanes inside the radiometer, the black vanes absorb more energy than the white vanes, which causes the black side to get hotter. This heat energy is transferred to the molecules that are in proximity to the black side of the vanes causing the molecules to move faster and hit the black side of the vane more often. The molecules eventually hit the side of the glass and transfer the energy to the glass and the process is repeated.

Ask students, “When an electrical current causes a light bulb to shine, is all of the electrical energy transferred into light energy or is some of the energy going into another source?” If students are struggling, ask them about what they would feel if they touched a light bulb. They should respond heat. Ask them if heat is a form energy. They should respond yes.

Make sure all six sources of energy are filled in on question 5 on page 18. See example below.
**Teacher note:** There are two overarching types of energy: stored energy which is called potential energy and motion energy which is called kinetic energy. The terms potential and kinetic energy are not used at this grade level in NGSS. It is recommended not to use these terms with students. One reason for this recommendation is that some forms of energy are a combination of both types of energy, for example electrical currents have both kinetic energy (due to the motion of the electrons) and potential energy (due to the charge on the particles). Sound is another example of energy that has both kinetic and potential energy. It is made up of longitudinal waves (compression waves) that have kinetic energy when the particles are spread out (areas with small concentration of dots below) and potential energy when the particles are compressed (areas with large concentration of dots below).

**Energy Transfer (10 minutes)**

Tell students we now want to look at the energy transfers that allow a wind turbine to generate electrical current. Ask students where the wind turbine originally got its energy from. The students should reply the energy came from the wind. Have students look at the list of types of energy and tell you what type of energy the wind has. Record wind/motion on the first blank of question 6 and have students copy this into their notebook. Ask students where the wind transferred some of its energy to. They should say the blades on the wind turbine. Ask them what type of energy these blades have. Record blades/motion on the second blank of question 6 and have students copy this into their notebooks. Ask students what form of energy is coming out of the wind turbine. Record electrical current on the last blank of question 6 and have students copy this into their notebooks.

Ask students what the energy in the wind turbine could be used for. Have a few students share their ideas making sure that they tell you both the source and form of the energy example. For example, if the source of energy is a stereo and the form of energy is sound, stereo/sound would be recorded. If they suggest an energy source that can produce multiple forms of energy, write them both down. For example, if the source is a lamp, the forms of energy would be light and heat (lamp/light, heat). Record one of the student’s ideas for question 7 and have students copy this into their notebooks.
Tell students that we now know the energy transfers that occur to convert the energy in the wind into electricity. We are now going to focus on how motion energy can be used to create an electrical current. Show students the magnet/electricity apparatus. Explain to students that the light bulb is attached to a coil of wire. But the wire is not plugged into anything. Quickly spin the handle of the apparatus to show that the light bulb does not light. Next, take one of the magnets out of the container. These magnets are extremely strong, so be careful when handling the magnets. Touch one of the magnets to a couple of the paperclips to show the students that the metal circles are in fact magnets. Next, attach the magnets to the magnet/electricity apparatus by placing one magnet on either side of the PVC pipe in the center of the apparatus. Do not allow the magnets to touch because it will be extremely hard to separate them. Show that simply having a magnet in the center of the apparatus also does not cause the light bulb to light. Quickly spin the handle of the apparatus to show that the light bulb does light when there is a moving magnet in the center of it. Ask students to describe what they are seeing and what was needed to get the bulb to light. They should say that there needs to be a moving magnet near a wire. Have students fill in question 8 in their notebooks.

**Teacher Note:** The voltage generated is proportional to the number of coils present. In order to generate enough voltage to light the bulb we need ~400 loops of wire.

Ask students what they think the blades on the wind turbine are turning inside the wide turbine housing. Record magnets for question 9. Ask students what the magnet must be near. They should respond a coil of wire. Tell students that most common ways of generating electricity such as burning coal and using uranium rely on turning large magnets to generate electrical current. Ask students what we would need to do if we want to produce the most amount of current. Students should respond that we would need to spin the magnets as fast as possible.

**Engineering Extension Building a Wind Turbine (10 minutes)**

Tell students that now that they understand energy transfer and wind turbines, they will give advice to a company called Windy Works that is looking to build a wind farm. Windy Works would like the students’ recommendations for where to buy land and how to build the optimal wind turbine. Remind students that in order for Windy Works to provide clean energy to people, they need to make sure they produce the most electricity for the cheapest price.

Ask students what type of area they would recommend that Windy Works purchase land. Students should say that Windy Works should purchase land in a windy area. Ask students why the wind turbine company should purchase land in a windy area. Try to have students reference their data from their experiments when justifying their answer. One possible answer is: when doing our experiment, we saw that as the fan distance increased, the current produced decreased, showing that less electricity is produced when there is less wind present. Have students fill in the answer for question 10.
If a group experimented with turbine angle, ask the students the following question: Windy Works can construct wind turbine heads that can swivel around the wind turbine base to keep the turbine angle always 90° to the wind. In order to construct these heads, it costs more money. Their other option is to construct cheaper wind turbine heads that are stationary. Would you recommend that they construct wind turbine heads that are adjustable? Why or why not? Possible student answer: we would recommend that they construct the heads that move because our experiments showed that the amount of current drops off quickly as the turbine angle (which is comparable to the angle at which the wind hits the turbine) moves away from 90°.

Have the students turn to page 20 in their notebooks.

Tell students we are now going to help Windy Works determine which values they should use for three different changing variables associated with manufacturing wind turbines: blade angle, dowel placement, and number of weights. Tell the students that they will go through each of the changing variables and circle the value that they think the company should use. After they complete this you will show them data that you gathered and they will box the value that the data suggests would be the “best” value for manufacturing the wind turbines. Remind students that “best” for Windy Works means producing the most current for the cheapest price. Read the manufacturing specifications that Windy Works has already decided that they will use for their wind turbines: “the blade material is cardstock...”

Have students circle which blade angle they think would allow a wind turbine to generate the most current. Then have students share their ideas as well as their thinking behind their answer. Try to have the students reference data from a group experiment if blade angle was picked as a changing variable. Show students the data that you took (page 9, picture packet). Have a student tell you what was plotted on the x-axis (blade angle) and what was plotted on the y-axis (current). Ask them which blade angle produced the most current (10°) and which produced the least current (90°). Ask them if they think the difference in currents is significant or if they think it is within the error of the measurements. Students should say that the blade angle affects the current significantly because they can clearly see a pattern that as the blade angle gets closer to 90° the current drops. Ask them if having an angle of 10° compared to 90° would change the cost of manufacturing the wind turbine. They should respond that it would not change the price because the same wind turbine head would be used for both blade angles. Ask them which blade angle they would recommend that Windy Works uses. They should respond 10°. Have the students box 10°.

![Effects of Changing Blade Angle](image)

Have students circle which dowel placement they think would allow a wind turbine to generate the most current. Then have students share their ideas as well as their thinking behind their answer. Try to have students reference data from a group experiment if dowel placement was picked as a changing variable. Show students the data that you took (page 10, picture packet). Have a student tell you what was plotted on the x-axis (dowel placement) and what was plotted on the y-axis (current). Ask them which dowel placement produced the most current (0.5 cm) and which produced the least current (6.0 cm). Ask them if...
they think the difference in currents is significant or if they think it is within the error of the measurements. Students should say that the dowel placement affects the current significantly because they can clearly see a trend that as the dowel placement gets farther away from the hub, the current goes down. However, the effects of dowel placement are not as great as blade angle. Ask them if having a dowel placement of 0.5 cm compared to 6.0 cm would change the cost of manufacturing the wind turbine. They should respond that having a dowel placement of 6.0 cm might cost the company more than having a dowel placement of 0.5 cm because more material is needed for the rod. Therefore, not only does 0.5 cm provide more current, it also might be cheaper to manufacture. Ask them which dowel placement they would recommend that Windy Works uses. They should respond 0.5 cm. Have the students box 0.5 cm.

Have students circle which number of weights they think would allow a wind turbine to generate the most current. Then have students share their ideas as well as their thinking behind their answer. Try to have students reference data from a group experiment if weight number was picked as a changing variable. Show students the data that you took (page 11, picture packet). Have a student tell you what was plotted on the x-axis (number of weights) and what was plotted on the y-axis (current). Ask them which number of weights produced the most current (6 and 9) and which produced the least current (3). Ask them if they think the difference in currents is significant or if they think it is within the error of the measurements. Students should say that number of weights does not affect the current significantly because there is no pattern seen in the amount of current as the number of weights increases. Ask them if having 0 weights compared to 12 weights would change the cost of manufacturing the wind turbine. They should respond that the more weight the wind turbine has, the more it costs because more material is needed. Therefore, it is cheaper to use less weights and having less weights does not decrease the current. Ask them which number of weights they would recommend that Windy Works uses. They should respond 0. Have the students box 0.
Tell students that now that they have the values of the variables that they would suggest that WindyWorks uses, we are going to test their recommendations. Ask students what amount of current they think a wind turbine would produce with these values and why. Students should suggest a value that is greater than 6.5 mA because this is the largest value that was seen in the graphs and it only has one of the ideal values. Tell students that you have set-up a wind turbine with their suggested values. Turn on the fan and have a student read the current off the multimeter. Record this value for question 12.

![Image of wind turbine current](image)

Tell students that they have taught you a lot about energy and wind turbines. You have learned that there are many different types of energy and that energy cannot be created nor destroyed, but it can be transferred. You have also learned that there are different ways to build a wind turbine to increase the amount of current that it will produce. Tell students that before you go, you are going to give them a short assessment to find out what they learned during both of the SciTrek modules they have worked on.

**Content Assessment:**
(10 minutes – Full Class – SciTrek Lead)

Tell students to close their SciTrek notebooks and to place the notebook in the corner of their desk. Pass out the Content Assessment to the students. Tell students to put their name, teacher’s name, and date on the top of their paper. During the assessment, remind students to work by themselves. Read each of the content questions to the students and have them select/fill out the correct answer. When students are finished, collect the assessments and verify that they have written their name on the assessment.

Tell students that they can keep their SciTrek notebooks and that you have enjoyed working with and learning with them, and that you hope they continue to see themselves as scientists and explore the world around them.

**Clean-Up:**

Bring all materials back to UCSB.
**EXTRA PRACTICE**

**Procedures**

**QUESTION**
If we change the **height** of the water tower, what will happen to the** temperature at which the water boils?**

**EXPERIMENTAL SET-UP**

<table>
<thead>
<tr>
<th>Changing Variable</th>
<th>Solid Type</th>
<th>Trial A</th>
<th>Trial B</th>
<th>Trial C</th>
<th>Trial D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sugar</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Salt</td>
<td></td>
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<tr>
<td></td>
<td>None</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Instructions**

Step 1: Read each statement and underline correct, circle changing variables and box information about data collection.

Step 2: Circle yes if the statement could be a correct step for a procedure about the question and experimental set-up above. If not, circle no.

| a. Put 10 g of sugar B salt C baking soda D tea in each beaker. | Yes |
| b. Light the awesome burner. | Yes |
| c. Put 340 mL of water into each 300 mL beaker. | Yes |
| d. Gather results from the experiment. | Yes |
| e. Put 10 g of baking soda into beaker C. | Yes |
| f. Increase the temperature of the solution both in | No |
| g. Put 1 g of different solid types into each beaker. | Yes |

Underline controls, circle changing variables, and box data collection.

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