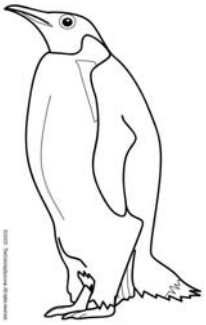


What is Engineering?
Perspiring Penguins

IMPORTANT NOTE:

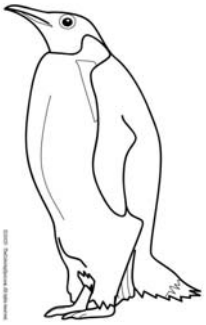
This Perspiring Penguins engineering design challenge was inspired by an engineering design-based science activity, geared towards middle school students, developed by Dr. Christine Schnittka at Auburn University (AL). Dr. Schnittka's unit, "Save the Penguins," teaches students about thermodynamics and heat transfer through the context of an engineering design challenge.

It is important to note the differences in educational goals between Dr. Schnittka's original "Save the Penguins" unit, and EiE's adaptation, "Perspiring Penguins." Dr. Schnittka's unit aims to help children confront the misconceptions they hold about heat, energy, and heat transfer. A series of scaffolded activities in "Save the Penguins" provide cognitive dissonance for children and encourage them to examine and redefine their ideas of heat and energy. EiE's "Perspiring Penguins," which is targeted toward educators (rather than students, as in Dr. Schnittka's unit), aims to reinforce and support educators' understanding of the Engineering Design Process and to make explicit the connections between science and engineering.

With elementary students (as opposed to adult educators), EiE recommends using Dr. Schnittka's unit. The scaffolding and support provided in the "Save the Penguins" unit increases students' science content knowledge, but also allows them to utilize this knowledge to successfully complete the engineering design challenge.

When facilitating this unit in your EiE PD workshop, please inform participants of its origins and provide them with links or references to the following resources:

- Dr. Schnittka's full "Save the Penguins" unit can be downloaded here: www.auburn.edu/~cgs0013/ETK/SaveThePenguinsETK.pdf
- Bell, R., Schnittka, C. (2010). Engineering design and conceptual change in science: addressing thermal energy and heat transfer in eighth grade. *International Journal of Science Education, December,* 1-27.
- Schnittka, C., Sheerer, K. (2012). Save the Boulders Beach Penguins. *Science and Children*, *March*, 50-55.
- Bell, R., Schnittka, C., Richards, L. Save the penguins: Teaching the science of heat transfer through engineering design. *Science Scope, 34*(3), 82-91.



What is Engineering?
Perspiring Penguins

Preparation: 20-25 minutes
Workshop: 45 minutes

Participants will:

- engage in a common engineering experience.
- realize that they naturally solve problems using a process similar to the Engineering Design Process (EDP).
- develop the five-step EDP that forms the backbone of the EiE units.

Overview

The "Perspiring Penguins" activity is best used with participants who are already familiar with EiE (e.g., participants who have attended a previous EiE PD workshop, taught an EiE unit, or both). The activity was inspired by the article "Save the Penguins: Teaching the science of heat transfer through engineering design" by Christine Schnittka, Randy Bell, and Larry Richards (*Science Scope*, 34(3), 82-91). The goals of the Perspiring Penguins activity are similar to those of the "What is Engineering?" (Tower Power) activity that is used in all introductory EiE workshops. This activity allows participants to act as engineers and design a technology to solve a problem. Through the process of engineering, participants' previous understanding of the Engineering Design Process is refreshed and reinforced.

In Perspiring Penguins, participants are introduced to an engineering problem through context—a zoo in Arizona needs a low-cost, energy-efficient outdoor enclosure that will keep its Emperor penguins cool in the sweltering Southwest climate. After asking questions to find out more about the constraints and criteria of their design challenge, participants work in small groups to try and solve the problem. After creating their designs, each group tests their enclosures and records data to analyze the success of their designs. The facilitator asks each group questions about their designs that encourage participants to reflect on their prior knowledge, the trade-offs that were considered, and the evolution of their final design ideas.

The facilitator then guides the whole group to articulate what they did to solve the problem and then relates their experiences to the steps of the Engineering Design Process, as presented in EiE materials. By immersing themselves again in the engineering experience, participants reinforce their existing knowledge of the EDP through activity and reflection. Their experience with this challenge serves as a focal point that the group can refer back to as they continue to delve deeper into the process of engineering as defined by the EiE curriculum.

Perspiring Penguins

Materials

For the Workshop:

- materials for sample bags:
  - 10 black felt squares, approx. 2” x 3” (5.1 x 7.6 cm)
  - 10 black foam squares, approx. 2” x 3” (5.1 x 7.6 cm)
  - 10 black construction paper squares, approx. 2” x 3” (5.1 x 7.6 cm)
  - 10 silver Mylar squares, approx. 2” x 3” (5.1 x 7.6 cm)
  - 10 aluminum foil squares, 2” x 3” (5.1 x 7.6 cm)
  - 10 copy paper squares, white, approx. 2” x 3” (5.1 x 7.6 cm)
  - 10 paper towel squares, approx. 2” x 3” (5.1 x 7.6 cm)
  - 10 rubber bands
  - 10 binder clips
  - 10 bags, plastic, re-sealable, sandwich sized
- 15 black felt squares, approx. 4” x 6” (10.2 x 15.2 cm)
- 15 black foam squares, approx. 4” x 6” (10.2 x 15.2 cm)
- 15 black construction paper squares, approx. 4” x 6” (10.2 x 15.2 cm)
- 15 silver Mylar squares, approx. 4” x 6” (10.2 x 15.2 cm)
- 15 aluminum foil squares, approx. 4” x 6” (10.2 x 15.2 cm)
- 15 copy paper squares, white, approx. 4” x 6” (10.2 x 15.2 cm)
- 15 paper towel squares, approx. 4” x 6” (10.2 x 15.2 cm)
- 15 rubber bands
- 15 binder clips
- roll of aluminum foil, approx. 7’ (2.1 m) long
- large plastic storage bin, approx. 12” x 12” x 18” (30.5 x 30.5 x 45.7 cm)
- 4 sheets of paper, construction, black, 9” x 12” (22.9 x 30.5 cm)
- 3 shop lamps, silver
- 3 lightbulbs, 100 W
- 2 gram scales that measure to at least hundredths of a gram
- ice cube tray, holds at least 8 ice cubes
- water
- thermometer, preferably digital probe thermometer

Perspiring Penguins

Materials (continued)

- tongs
- 1 oz. (29.6 mL) shallow plastic cup
- insulated lunchbox (with cold packs)
- masking tape

For Each Group (Assume Groups of Three to Four Participants):

- ice cube (see Preparation section below)
- container, cylindrical, deli, plastic, clear, approx. 12 oz. (0.4 L)
- scissors
- calculator (optional)
- stopwatch with second hand or other method of accurately tracking time
- 1 roll of tape, cellophane
- copy of *Penguin Enclosure Testing* {PD-1}
- copy of *Perspiring Penguins and the EDP* {PD-2}
- list of references listed on p. 1 of this section, either as a handout or on a PowerPoint slide

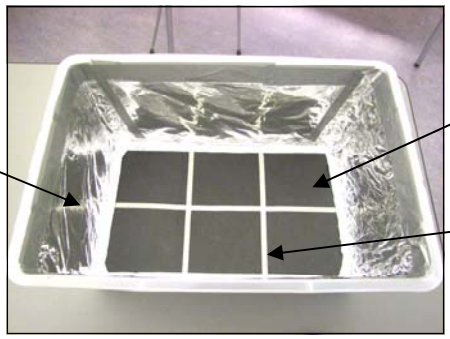
Preparation

1. Fill the ice cube tray with water and leave overnight in a freezer to create ice cube "penguins" for participants to use during the workshop (see photograph below). Before you leave for the workshop, pack the penguins in the insulated lunchbox with cold packs so they do not melt. If possible, store them in a freezer at the workshop location.

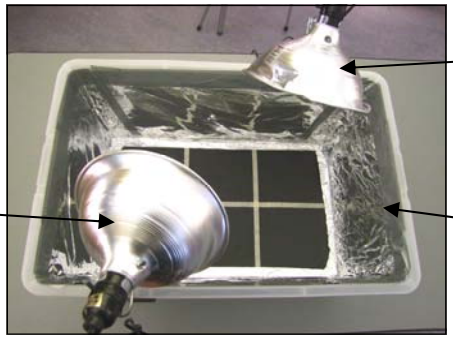
Perspiring Penguins

2. Assemble the bags of sample materials. Cut the felt, foam, Mylar, aluminum foil, copy paper, construction paper, and paper towels into rectangles of about 2” x 3” (5.1 x 7.6 cm). For each group, place one rectangle of each material, one binder clip, and one rubber band into a plastic re-sealable bag.

3. Create the testing chamber that will simulate an Arizona summer climate:
   - Line the bottom of the plastic storage bin with the black construction paper.
   - Create a grid on the bottom of the testing chamber with the masking tape. The grid should be taped so that the masking tape forms six even squares on the bottom of the testing chamber.
   - Line the inside walls of the four sides of the bin with aluminum foil.

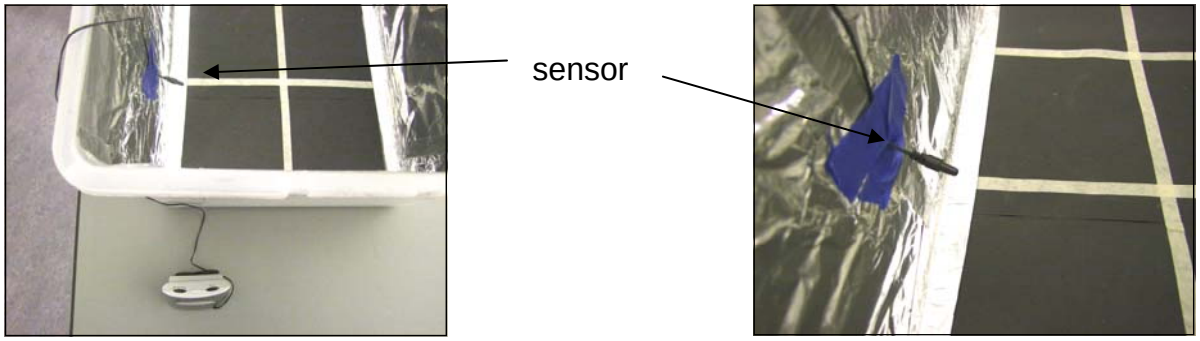


   - Attach the shop lights so they face into the bin and will shine into it when they are lit.



Perspiring Penguins

4. On the day of the workshop:
   - Be sure to turn the shop lights on at least 30 minutes before beginning this activity so that the testing chamber has time to heat up.
   - Tape the thermometer's sensor to the wall of the testing chamber to ensure it is measuring the temperature of the air—not the walls or bottom.



   - Set up a materials table by laying out all the available materials participants can use to make their penguin enclosures: felt, foam, Mylar, aluminum foil, copy paper, paper towels, rubber bands, binder clips, tape, and scissors.

Perspiring Penguins

Activity

1. Ideally, your participants will have already experienced the "What is Engineering?" (Tower Power) activity in a previous EiE workshop. Tell participants that they are going to work as engineers to solve another short engineering design challenge. Explain that the goal of this activity is to give them another common engineering experience to help reinforce their knowledge of the Engineering Design Process.

2. Set the context for the design challenge with a short story:

   - A zoo in Phoenix, Arizona is planning on opening an Emperor penguin exhibit. The zoo needs participants to design a low-cost, energy-efficient outdoor structure to house the Emperor penguins.

3. Display your miniature Phoenix climate (the testing chamber with the shop lights attached to it and turned on). Explain that this is a model of the AZ climate where the zoo is located and where the penguins are going to live. Ask participants:

   - **What is the problem that you need to solve?**
     Common responses: Phoenix temperatures are too hot for the Emperor penguins; they won't be able to survive in such extreme heat.

   Record their thoughts on chart paper or the board under the heading "What is the problem?" (see example to the left).

Write on Chart Paper:

What is the problem?

In order to solve this problem, what do you want to know?

Perspiring Penguins

4. Tell participants that it is going to be their job, as engineers, to solve this problem. Ask:

   - **In order to solve this problem, what do you want to know?**

   List the participants' questions on chart paper or the board. Gather all questions before answering any of them. Critical questions that need to be asked (and answered) before the participants attempt the challenge include:

   - *What materials are available?*
   - *How much time do we have?*
   - *What is the budget?*
   - *How will we know if we are successful?*
   - *How much space does each penguin need, and how many penguins does each enclosure need to hold?*
   - *How big is the enclosure?*
   - *How long will the penguins need to stay in the model Phoenix?*
   - *How will we model the penguins in order to test our designs?*
   - *How cold does the temperature need to be inside the penguin enclosure?*
   - *How hot is Phoenix?*
   - *How cold does a penguin need to be in order to stay healthy?*
   - *Where will the visitors be in relation to the penguins?*

   Other common, but not critical, questions that participants often ask are:

   - *What kinds of foods do penguins eat?*
   - *Is there an electric power source?*
   - *Do the penguins need separate areas within the enclosure for sleeping and eating?*

PD Tip

You might point out to participants that, through their questions, they are identifying the criteria and constraints of their design challenge. Work as a group to define those terms:

EiE uses **constraints** to describe the limitations on a design, such as resources (e.g., time, materials, and human-power).

EiE considers **criteria** to be specific qualities of a successfully designed solution. For example, strength, durability, reliability, and speed can all be criteria for a design.

Perspiring Penguins

PD Tip

Before explaining the testing method to participants, encourage them to come up with a procedure for evaluating the success of their designs on their own. Questions you might ask to prompt their thinking are:

- **How will you know if your enclosure provides a safe environment for penguins?**
- **How could you test your enclosure to evaluate how successful your design is?**

It is very likely that participants will come up with the procedure outlined at right after being asked the above questions, but if they are struggling remind them that the shop lights and bin are being used as models for Arizona's climate and that the ice cubes are models for the penguins. Ask:

- **How could you use our models to evaluate the success of your design?**

PD Tip

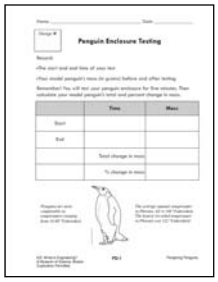
To promote large-group thinking and to reduce competition, tell participants to consider themselves a large group of engineers who want to generate as many solutions as possible and who will work in smaller teams. Teams should feel free to compare ideas, borrow, and use inspiration. The goal is to learn as much about engineering and what materials make the best penguin enclosure possible.

5. Separately address each of the questions raised by participants. Make sure to include and, if necessary, add the following information:
   - You must use the deli container as the base for the model penguin enclosure. You can design a floor and a roof for the enclosure.
   - Each enclosure will hold one penguin.
   - You cannot cover the sides of the penguin enclosure. Visitors must have a 360° view of the penguin.
   - The materials available to you are black felt, black foam, black construction paper, Mylar, aluminum foil, white copy paper, paper towels, rubber bands, binder clips, tape, and scissors (hold each material up for participants to see as you list them).
   - You can use a total of five pieces of material in your design. You must use five different materials, not including the tape or scissors.
   - The penguins will be modeled using ice cubes.
   - The model penguin will be placed in your enclosure, which will then be placed in the model of Phoenix, Arizona (the testing chamber) for five minutes.
   - The model penguins will be weighed before and after they have been in the testing chamber in order to evaluate the success of your design.
   - Emperor penguins are most comfortable in temperatures ranging from 14° to 68° Fahrenheit.
   - The average body temperature of an Emperor penguin is 102° Fahrenheit.
   - The average summer temperature in Phoenix is 106° Fahrenheit. The hottest recorded temperature in Phoenix was 122° Fahrenheit.
   - You have 18 minutes to design and build your penguin enclosure.

Perspiring Penguins

6. Divide participants into groups of three to four.
7. Distribute the handout *Penguin Enclosure Testing* {PD-1} to each group, and go over it together. Make sure participants know that on the handout they will need to record the time they place the penguin into the testing chamber and the time they take it out, as well as the ice cube's starting and ending mass in grams, as measured on the gram scale.
8. Distribute the sample bags so that participants can examine the available materials before choosing which materials they will use.
9. Once participants have decided on materials, have them collect their materials and tools and get to work on their design. As groups are working, circulate and ask:
   - **What are you designing?**
   - **What materials did you decide to use? Why?**
10. When participants are done creating their designs they should bring them over to the testing chamber for testing:
    - Make sure you have tared the gram scale with the small shallow plastic cup on it.
    - Use the tongs to take one ice cube out of the lunchbox and place in the small, shallow plastic cup.
    - Place the cup on the gram scale and measure the ice cube's mass in grams. Participants should record their penguin's starting mass on *Penguin Enclosure Testing* {PD-1}*.*
    - Use the tongs to take the ice cube out of the small shallow plastic cup and place it in the participants' penguin enclosure.
    - Have participants place their enclosure in one of the squares formed by the grid. Remind participants to start the stopwatch or timer as soon as their design is placed in the testing chamber.

Penguin Enclosure Testing
{PD-1}


Penguin Enclosure Testing

PD Tip

If there are more groups than squares on the grid, have later groups wait until the first groups have finished testing before adding their enclosures to the testing chamber. There should be only one enclosure in each square of the grid at a time during testing.

Perspiring Penguins

- After five minutes, have participants remove their penguin enclosure from the testing chamber.
- Use the tongs to take the ice cube out of the enclosure and measure on the scale again. Participants should record the final mass and then fill out the rest of *Penguin Enclosure Testing* {PD-1}.
- Make sure to wipe out the small plastic cups between testing so results are as accurate as possible.

11. Make sure all groups have at least begun testing at the 18-minute mark (the time constraint for designing and creating their enclosures).

12. Once each group has had a chance to test their designs and record their data, have each group share their penguin enclosure design with the rest of the workshop. Ask each group:
    - **What are some of the materials your team decided to use, and how did you use those materials in your design?**
    - **Why did you choose those materials?**
    - **How would you improve your enclosure if we had time?**

13. If it fits in with your discussion, you might point out that participants' assumptions and statements may evoke questions that could be answered using inquiry-based science. For example, the common belief that thicker materials keep objects warmer than thinner materials may evoke questions about thermal insulators and conductors. In addition, this challenge connects to life science topics such as basic needs of animals and thermoregulation.

PD Tip

If any participants' penguin enclosure designs are particularly unsuccessful, remind them and the whole group that learning from failure is valuable and that the Engineering Design Process incorporates this experience in the "Improve" step. Children often have difficulty with this step so participants might want to brainstorm different ways of responding when a child's engineering design fails.

PD Tip

In this activity, the colors of the materials were intentionally chosen to force participants to consider the "trade-offs" inherent in every engineering project. For example, the materials that are the best insulators (such as the foam and felt) are also black, so they absorb the most heat. The materials that are poor insulators (such as copy paper and foil) are also white or reflective, so they absorb less heat.

Perspiring Penguins

Reflection

1. Ask participants to think about what they and their teammates did to create their penguin enclosures:

   - **What are some of "action words" that describe what you did during the design process?**
     Common responses: brainstorming, cutting, planning, talking, stressing, taping, modifying, examining materials, etc.

   List participants' responses on the board or chart paper (see example at right).

2. Post a diagram of the EDP for participants to see (see example at right). Tell participants that they are going to refresh their knowledge of the Engineering Design Process by organizing the "action words" into the steps of the EDP to which they correspond. Have participants work in the groups with which they designed their enclosures.

3. Distribute the handout *Perspiring Penguins and the EDP* {PD-2}, and give groups 5-7 minutes to organize the "action words" listed on the board or chart paper into the steps of the EDP.

4. After groups have finished working, have one group come up for each step of the EDP and write down the "action words" next to that step. Have participants explain why they chose those particular "action words" for that step.

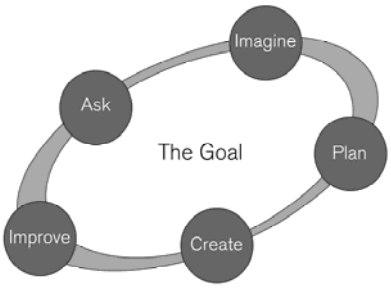
5. If applicable, ask participants:

   - **In your experiences teaching EiE in the classroom, which step of the EDP did you observe students struggling with the most?**
   - **Why do you think they struggled with that step?**
   - **How did (or could) you support students so that they are more successful in using the EDP to solve problems?**

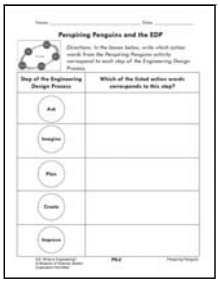
Write on Chart Paper:

Describe what you did during the design process.

The Engineering Design Process



Perspiring Penguins and the EDP {PD-2}



Perspiring Penguins

6. Explain that these five steps of the EDP, as described by EiE, are a general summary of the cyclical nature of the development of technology. Ask participants:

   - **Why do you think the diagram of the EDP is represented as a circle?**
     Common response: The EDP is represented as a circle because there is no specific "starting" or "ending" point in the Engineering Design Process, it is cyclical/iterative in nature. Engineers often start at different steps of the process, and technologies are constantly being improved, meaning that the process doesn't have a clear ending point.
   - **Does the EDP always start by asking questions?**
     Common response: No. Engineers often work to improve existing technologies so they start with the "Improve" step.

7. Summarize this activity by noting that it flows in a similar manner to EiE units. In EiE units, students are introduced to the Engineering Design Process and the challenge's context through a story. In addition, the five-step EDP highlighted here is the process that students use in Lessons 3 and 4 of every EiE unit to guide them as they design and improve a technology. Finally, be sure to point out that in this activity, the Engineering Design Process was a problem-solving process that the participants used quite instinctively and that this is true for their students as well.

8. Explain to participants that this "Perspiring Penguins" engineering design challenge was inspired by the "Save the Penguins" unit developed by Dr. Christine Schnittka, which integrates science content about heat and energy with an engineering design challenge. While the "Perspiring Penguins" activity was designed for adult learners, if participants wish to implement this design challenge in their classroom students, EiE highly encourages them to use Dr.

Perspiring Penguins

Schnittka's version, which can be downloaded for free at:

- www.auburn.edu/~cgs0013/ETK/SaveThePenguinsETK.pdf

9. Distribute the handout or post the list of references to Dr. Schnittka's unit and articles.

Name: _____ Date: _____

Design #

Penguin Enclosure Testing

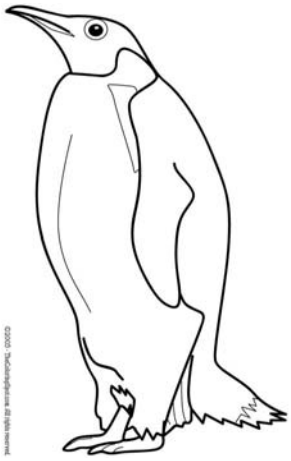
In the table below, record:

- the start and end time of your test,
- your model penguin's mass (in grams) before and after testing.

Remember! You will test your penguin enclosure for five minutes. Then, calculate your model penguin's total and percent change in mass.

	Time	Mass
Start		
End		
	Total change in mass	
	% change in mass	

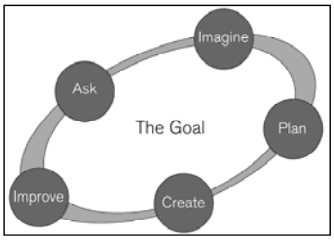
Penguins are most comfortable in temperatures ranging from 14-68° Fahrenheit.



The average summer temperature in Phoenix, AZ is 106° Fahrenheit. The hottest recorded temperature in Phoenix was 122° Fahrenheit!

Name: _____ Date: _____

Perspiring Penguins and the EDP



Directions: In the boxes below, write which action words from the Perspiring Penguins activity correspond to each step of the Engineering Design Process.

Step of the Engineering Design Process	Which of the listed action words corresponds to this step?
Ask	
Imagine	
Plan	
Create	
Improve	