Environmental Science Institute
THE UNIVERSITY OF TEXAS AT AUSTIN

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The Sun as Your Houseguest: Concepts in Insulation & Energy

Lesson plan for grades 9-12
Length of lesson: 1 Class Periods (75 minutes)
Authored by: Texas State Energy Conservation Office, "Renewable Energy Guide for Buildings"
Adapted by: Jesús Aguilar-Landaverde, Environmental Science Institute, May 4, 2012

SOURCES AND RESOURCES:

- Texas' Renewable Energy Sources: Texas Energy – Past and Present
  http://www.infinitepower.org/txenergy1.htm
- US EPA Recommended Levels of Insulation
  http://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_insulation_table
- US Dept. of Energy on Voltaic Cells
  http://www.eere.energy.gov/basics/renewable_energy/pv_cells.html
- Original Reading Passage and Activity
  http://www.infinitepower.org/pdf/No16%2096-823B.pdf
- The Efficient Windows Collaboration (U-Values)
  http://www.efficientwindows.org/ufactor.cfm
- US Energy Information Administration: Annual Energy Review
  http://205.254.135.24/totalenergy/data/annual/showtext.cfm?t=ptb0201a
- California Energy Comission on Building Orientation
  http://www.consumerenergycenter.org/home/construction/solardesign/orientation.html
- EcoWho and Building Orientation
  http://www.ecowho.com/articles/6/The_importance_of_building_orientation.html

POTENTIAL CONCEPTS TEKS ADDRESSED THROUGH THIS LESSON:
§112.37.c Renewable Energy, Grade 11-12: 2I, 6B, 9J
§111.32.b Mathematics, 2B, 2C, 2D

PERFORMANCE OBJECTIVES (in order of increasing difficulty to permit tailoring to various age groups):
Students will be able to:

- Report what is meant by ideal building orientation.
- Compare and contrast the efficiency of various insulating materials.
- Measure, record, and plot data on the efficiency of these materials.

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MATERIALS (per group of four):

- Water
- 2 Dixie cups per test material
- Water
- A freezer
- 4 Graduated cylinders (10 or 25 ml size range) per test material
- Packaging tape
- Miscellaneous insulating materials to test (commercial insulation pieces, Styrofoam, cotton balls or batting, fabrics, packing peanuts, paper towels, newspaper, bubble wrap, etc.)
- 4 Rulers
- 1 poster board
- 4 markers
- 1 stapler
- 4 Goggles

CONCEPTS:

Day Lighting is using natural light to provide lighting for interior spaces, such as well-placed windows
Energy Efficiency is using less energy to perform the same function.
R-Value is a numerical scale for insulation value (R-6 is a low value; R-30 is a high value)
SHGC (Solar Heat Gain Coefficiency) is a measure of the amount of solar energy that a glazing material allows to pass
U-Value is a measure of the rate of heat loss or gain through a material; the lower the U-factor, the greater the material's resistance to heat flow and the better its insulating value (U-value is the inverse of R-value)
Thermal Insulation is the method used to help prevent or reduce the flow of heat

BACKGROUND:

The proper design, construction, and maintenance of buildings can have a significant, positive impact on the environment and natural resources. According to the U.S. Department of Energy, residential and commercial buildings used one-third of all the energy and two-thirds of all electricity consumed in the U.S. in 2010. As efforts are directed at identifying and developing cleaner alternative energy sources, parallel efforts in energy efficiency will go a long way to meeting energy demands, thereby reducing environmental impacts of energy production through fossil fuels.

This lesson focuses on just one way to conserve energy and reduce energy costs while still preserving desired comfort levels when designing and building homes and businesses. That is, building can be made more energy efficient through better insulation and weatherproofing. This approach—also including reducing air pollution, conserving energy during construction, using recycled and recyclable

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materials, and other factors—to building and designing is known as "green" building. This is critical to helping our existing energy infrastructure meet energy needs across Texas, the United States, and the world.

<u>PREPARATION</u>:
Because this activity uses many cups, it is probably best to divide the class into groups of four or so. This will reduce both the amount of materials needed and the space needed in a freezer for the preparation. It is at the teacher's discretion whether to follow the suggested procedure in the lab file. Since this modified lesson plan is for one class period, I recommend freezing all necessary cups one night before the day of the lesson, per instructions in the lab activity sheet (Step 1).

<u>ENGAGE: (10 min)</u>
Open a discussion, (especially if the classroom is devoid of windows), with a simple question: "Which way is North?" I also imagine that after less than a minute, the students will begin to reach a consensus on the correct direction. Afterwards, you might ask, "Which way does your *house* face?" Here some students may have higher spatial awareness than others, and so answers may vary. Nevertheless, the question that truly lends itself to opening the following activity is, "Why?" That is, *why* do homes face the way they do?

Note to teachers:
As often occurs in construction, ideal orientations and locations for homes are not always met. The idea, even if it turns out that the majority of the students' homes are not ideally oriented, is for the students to deduce exactly what *is* proper orientation. More importantly, they should discuss *why* this is so. That is, it is a common misconception that the sun rises in the East and sets in the West. This occurs on the equinoxes, but it is not the case for the remainder of the year. In the Northern Hemisphere, the summer sun rises in a more northern part of the sky and reaches a higher position in the sky. The reverse is true for the sun in the winter. A home in the northern states, all other factors aside, would then have an ideal orientation of south. During the winters, thus, the southern façade of the building would be able to gain solar heat—thereby reducing heating energy loads from electricity.

It is not necessary to introduce any technical terms at this stage; the concept of harnessing the sun's "free" heat should be emphasized. This is facilitated not only by the orientations of buildings but also the insulating materials used in construction. Namely, the proper insulation of a house or building helps these structures retain their internal temperature in spite of external changes in temperature.

Some questions to transition may include:
- What keeps our homes warm during the winter?
- Where does the energy from air conditioning come from?

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- What effects might orientation of a house or a building in our town have on the costs of heating during these seasons?
- Is there anything else? Do some rooms in your house become hotter or colder faster than others? Why?

More simply, what can you tell me about the cups fast food restaurants use for different drinks? How can this extend to building a house? What purpose do these cups serve (besides holding liquids)?

EXPLORE: (45 minutes)

This section contains the original lab activity produced by the Texas State Energy Conservation Office (see Web link in SOURCES AND RESOURCES). A modified procedure for students is reproduced below with annotations.

1. Use one of the cups as a template to draw a number of circles on the poster paper equal to the number of cups in the freezer. Carefully cut out each of the circles. The insulated container you design will hold the frozen Dixie cups. The poster paper circles will become lids for the insulating containers.
2. Choose your insulating materials, which will vary by group. You will also be testing one of the insulating materials in 3 varying degrees of thickness for comparison.
3. Wrap 1” of one the insulating materials around one container and tape or staple the materials in place. If you are using stiff Styrofoam, you will have to cut it in thin strips to fit around the circular cup. The packing peanuts may best be stuck to tape first and then secure the tape to the cup. Also cover the lid. Use tape sparingly, as it will add to your insulation and affect your results. Repeat this step with the other insulating materials being tested. Label each cup with your group name or number and assign numbers to each cup. Record the materials being used on Data Table 1.
4. Choose one test material and prepare 3 cups in the same manner as Step 6, except you will use 3 different measures of thickness. Record the measures of thickness on Data Table 2.
5. Store your labeled “designer insulated cups” as instructed.
6. Place your prepared “designer insulated cups” with the 3 different test materials on the lab table.
7. In a lab notebook or other medium approved by the instructor, answer the following questions:
    a. Which material do you predict to be the best insulator? Why?
    b. Predict how, if at all, the insulating efficiency of a material changes with thickness.
8. Obtain the frozen cups prepared beforehand.
9. Place each frozen cup into a “designer insulated cup” and immediately place the cover on top. Do this for each of your designer cups.
10. Place your “designer insulated cups” with the frozen cup inside in the sunlight, if possible, or as instructed by your teacher. Record the time.
11. Every 4 minutes, uncover your insulated design and carefully pour out any melted water into a graduated cylinder, being sure to keep the remaining ice in the cup. Re-cover immediately and return the cup to the sunlight. Repeat for each of your insulated cups. A unique graduated cylinder should be used for each type of test material to keep each measurement separate.

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12. On Data Table 1 record the amount of water melted by the designer insulated cup in a total of 20 minutes. (Do this for each different designer insulated cup you are testing.)
13. Repeat Steps 1 - 5 with the 3 cups of one material in 3 different thicknesses. On Data Table 2 record the amount of water melted by the insulated cups in a total of 20 minutes.
14. Complete your Data Tables and share your information as instructed by your teacher, so that a bar graph can be constructed showing the amounts of melted water for the various kinds of materials used. (The least amount of melted liquid indicates the best insulator.)
15. Construct a scatter plot (x-y graph) of the amount of water melted versus thickness. Thickness is the independent variable so it goes on the x-axis.

Notes for Instructor:
Placing the cups in the sunlight is the best arrangement because it simulates exposure to solar energy; however, heat lamps or even ordinary desk lamps can be used. If an electrical heat source is being used, pretest the distance of the source away from the cups to be sure the ice does not melt artificially fast and advise the students of that distance. The smaller the amount of melted liquid produced, the better is the insulation.

If students are broken into groups of four, then this activity can be decreased in time significantly. That is, have one student be the record-keeper while the other three each carry out a separate experiment first with the different insulating materials and secondly with the varying thickness of a single material. The students should all be accountable for all data recorded, however, and should turn in individual completed worksheets.
Since this process may take some time, you may wish to give the students a time limit for each step of the process to advance.

EXPLAIN: (10 minutes)
After the allotted time has elapsed, gather the students' attention. Materials need not be collected, but work from the previous section should cease to promote discussion. These are some sample questions to open discussion. Introduce the terms R and U values at this point.

- Which was the best insulator?
- Was there a noticeable difference in the varying thicknesses of the materials tested?
- Would you want to build a house using the same insulating materials in Texas as in Montana? Why or Why not?
- What changes?
- How about windows? How do they contribute to saving energy, if at all?

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ELABORATE: (10 minutes)
Students should now be challenged to extend and apply their knowledge about insulation by performing an insulation efficiency calculation. This is a math problem that expands on the definitions of R-Value, the numerical scale for insulation degree.

The R-value for an insulator is much like the electrical resistance of a material; it is the measure of the termal resistance of a given insulator. One way to calculate power loss per unit area is to divide the temperature difference across an insulator by the R-Value. In US customary units, the units of R-Value are h*ft^2*ºF/Btu. For this problem, no conversions should be necessary.

One of the highest recommended R-values for attic insulation in central Texas by is R49. On a hot summer day in 2011, a recorded temperature was 103ºF. Assume that an insulated attic in this particular city is maintained at a constant 68ºF. Ignoring all other forms of heat transfer, calculate the power loss across the walls of this 2000 sq. ft attic.

How does this compare with the lower limit of recommended R-Value for the same region of R30?

For this problem, I found 1428.6 Btu/h. Or, 418.7 W (1 Btu/h ~ 3.4 W). A lower R-Value would result in a greater power loss.

EVALUATE:
The following data is from the Residential Prescriptive Requirements 2009 International Energy Conservation Code (IECC).

For this exercise, the students will be given six pieces of data. Each set of R-Values has a one-to-one correspondence to the counties listed. Using previously discussed data on insulation, have the students discuss in small groups but individually record their answers, explaining their reasoning for their pairings. The emphasis here is that at colder climates (northern Maine), higher values of resistance are needed to minimize power loss per square foot during the extreme cold temperatures of winter. In Arizona, however, not nearly enough resistance is needed during the same time of year to maintain a building at the same temperature.

1. Aroostook County, Maine
2. Pima County, Arizona
3. Lincoln County, Kentucky
4. Ceiling R-Value: 30 Floor R-Value: 13
5. Ceiling R-Value: 38, Floor R-Value: 19
6. Ceiling R-Value: 49, Floor R-Value: 38