Engineering to do Nothing

Put to work the basic astronomy knowledge of 10-14 year olds in teaching passive solar house design

Photographs: Susan Lewicki, Meadowlands Environment Center

By **Susan Lewicki**

MOST TEACHERS TURN THE LIGHTS OFF after students leave the classroom. I turn the lights off when students come in.

I always ask, "Can everyone still see well enough to read, write, and work on a project?"

"Yes!"

"We're already conserving energy, thanks to the Sun!"

So we begin learning with the lights off, but not in the dark.

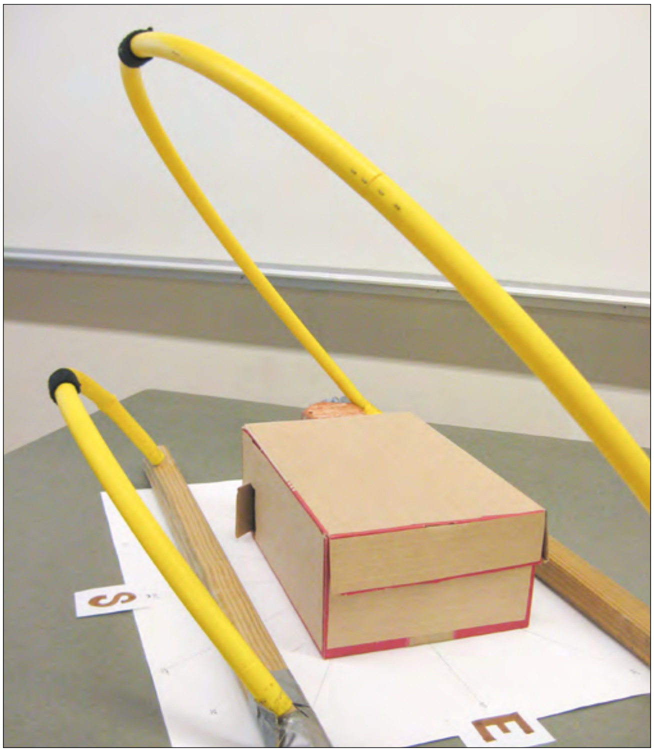
Teaching children about living more sustainably with the environment often focuses on conserving resources and habitats. But looking at this issue deeper, we might consider why the human landscape demands so many resources from natural landscapes in the first place. A lifestyle devoted to the accumulation of "stuff" is certainly a factor. However, no matter your lifestyle, even the buildings where we live, learn, work, and play are often resource intensive by design. Any strategy to live or teach the next generation about living more sustainably should involve how to redesign our built environment to provide the desired results.

Although the residential sector consumes less energy than do industry and transportation, children most readily connect with the places where they live. While a lot of attention is being put on increasing the amount of energy derived from renewable resources such as solar, wind, water, it can be expensive to outfit a classroom with enough solar cells, turbine kits, and multimeters for a worthwhile hands-on experience. And of course, each alternative energy technology carries its own issues; including siting, low efficiencies, and wildlife impacts.

Conservation habits can go a long way in cutting energy needs (and bills!) for a family, but passive solar design can enable upper elementary and middle school students to take up the challenge of designing an energy efficient home which requires less input from any active energy source. In the following paragraphs I outline how you can have your students investigate the energy principles associated with passive solar design using simple shoebox models and flashlights.

Passive Solar Home Design

Active solar energy systems (i.e. photovoltaic panels, water heaters) are receiving a lot of attention for home installations, but the Sun can lend a hand in a low-tech, low-cost way. Passive Solar Energy is a "Couch Potato's Light and Heat", requiring no additional equipment or maintenance beyond a building's initial construction. We simply recognize and honor the apparent motion of the Sun across the



A recycled hula hoop creates visible reminders of the path of the Sun through the seasons for our 40 degrees North latitude location. The smaller arc represents the Sun on the Winter Solstice, only covering a southeast-to-southwest path. The large arc shows the Summer Solstice with its 15-hour day. These were plotted from data provided at http://sunposition.info/sunposition/spc/locations.php .

sky over the course of the day and the seasons. Passive solar design attempts to freely invite the Sun's light and resulting heat into our homes during cooler months, while excluding direct light during the summer season. Most modern homes still have active heating and cooling systems installed, but passive solar design can greatly reduce the energy, resources and cost required for lighting and thermal comfort.

The Meadowlands Environment Center, where I work, hosts numerous field trip programs focused on "green" architectural design. This informal education facility became the first publicly-owned building in the State of New Jersey to receive Platinum certification from the United States Green Building Council. The USGBC's Leadership in Energy and Environmental Design (LEED) program sets guidelines and technical criteria for sustainable buildings. Site planning, water conservation, and sustainable materials have all contributed to a more responsible construction. For energy conservation, actual data collected from the building's monitoring system indicates that it demands about one seventh the electricity per square foot of an older "traditional" office space. A great deal of this energy efficiency derives from the building's orientation, roof, windows, and surrounding landscape, all specifically designed with the sun in mind! A photovoltaic array then offsets our electrical grid demand by another 29 per cent. The energy performance of this building was no accident – it was designed.

At the Meadowlands Environment Center, our "green building" field trip programs are some of our most popular, especially through the winter months. In our Solar Energy Design classes, students first study the Center's architecture for design exemplars and then apply these concepts to creating small house models working with the Sun. However, no matter what building you may teach from, anyone can share passive solar design ideas with students. Having windows with a view of the Sun is a bonus, but if your students have to go to another part of your building for that view, that's part of the lesson.

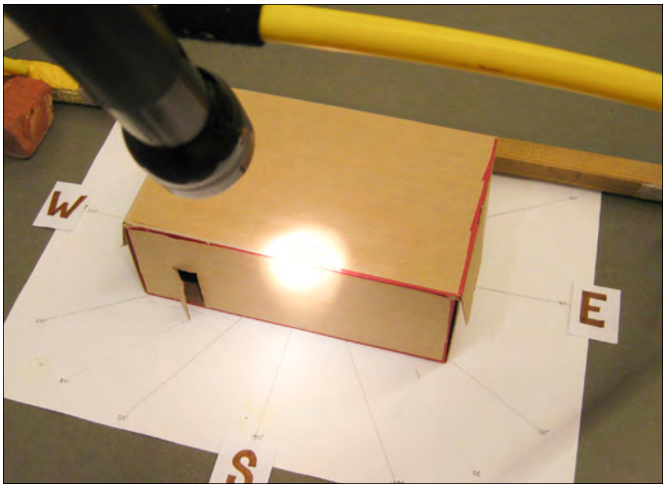
Sharing with Students

Begin by introducing students to Earth's closest star — the Sun — and to the idea that for millennia, people have *had* to plan their lives around its cycles. Before electricity, even something as simple as seeing inside your home was either totally dependent on some form of fire or allowing light inside. To do that, you would have to know where sunrise and set would be, and how the sun would move across the sky through the different seasons. Could that heat energy also be invited into our homes in the colder months? Could its energy be restricted in the summer? These ancient questions remain the essence of modern passive solar design.

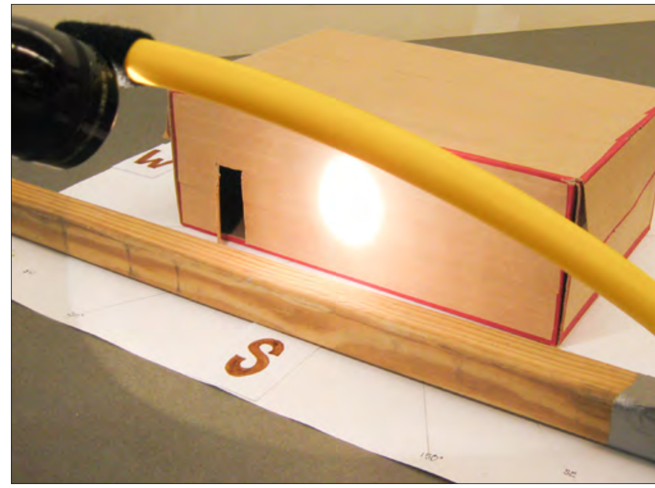
Most students at this level are academically aware of the Sun's motion, but aren't quite sure what that has to do with the energy needs of a building. Using a plain shoebox, a flashlight, and arcs cut from sections of a hula hoop, you can model for your students the rising, midday, and setting sun at your location through the seasons. The Meadowlands Environment Center is located at 40 degrees North latitude, so our particular models of the December and June solstices highlight those two extreme solar paths.[1] With a plain box out in the open, students can now see that the solar path through the seasons does change dramatically. They also recognize that the box, in its current state, won't get much help from the Sun in winter, and it may also bake the family inside in the summer! Unless that family wants to use a lot of active energy to light, heat and cool this house, we need to redesign.

Teams of students are challenged to modify the initial model to take full advantage of the winter sun while minimizing light and heat gain in the summer. With some discussion, students recognize that the addition of windows, changes to the roof, and some landscaping may help. Other modifications may include the building's overall shape, orientation, colors, or insulation. In line with experimental or engineering practices, each team takes on one variable and tests several designs.

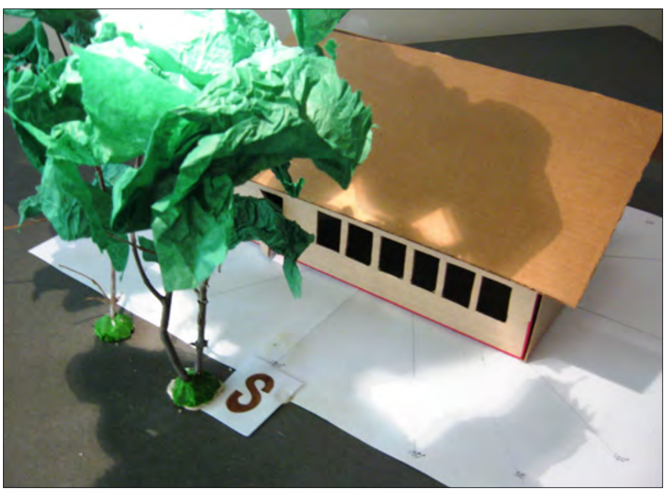
The criteria for success are maximum light penetration into the house (and possibly resulting heat) in the winter and a minimum in the summer. Depending on the actual age of the students and measurement tools available, you can set more specific assessment standards as well. Younger children can simply demonstrate light penetration with a yes or no. Older students can begin to quantify their results by laying a grid down inside the model and measuring the fractional floor area lit by the midday Sun for the various seasons ("the light went a quarter of the way across the room"). Equipment permitting, middle school students could actually measure temperature changes inside the house with a sensitive thermometer or probe after a specified light exposure period.



Noon sun summer



Noon sun winter



Complete model summer

Complete model winter

Constraints

- **Budget** – One option with older students is to give them a hypothetical budget with which to "green" their home and a price list for architectural and landscaping features. Teams have to decide on a roof style, how many windows to install, tree plantings, etc. We purposely set a mid-range budget so that students cannot afford everything on their wish lists and have to pre-plan their designs. For instance, we set a US $10,000 budget for energy features. Energy-efficient windows, doors, or trees are all $500 each, while a single solar panel (not enough to power the whole house) costs $1500. I personally love observing the social interactions as different teams prioritize expenditures.
- **Materials** – Everyday craft supplies work just fine for these models. We initially thought we'd have to purchase expensive "science kits" for our very high-tech kids. However, we quickly discovered that, even if they've created entire simulated kingdoms on their home gaming systems, many of them have never built any kind of physical model before. In that these houses are not load-bearing, shoeboxes, posterboard, and colored construction paper are sufficient to make a project that looks like a house. If you want to collect actual temperature data, clear packing tape can be used to seal any holes cut for windows to minimize radiative losses. For landscaping, bare tree branches propped up with clay make excellent deciduous trees at this scale. Crumpled tissue paper added to the branches provides convincing summer foliage. There is something novel about simple materials, and they often allow for more creativity, so teams jump right in to get the job done.
- **Time** – It is a happy problem indeed when your students don't want to stop working! After the building tour, our trip schedule usually allots students about 45 minutes for their preliminary designs, and there is a mad rush to prepare to share their successes.

After teams have worked on and discovered an efficient design for their individual variables, they spend 25 minutes presenting to each other what worked best. It is in this sharing in the students' own words, that as a teacher you can divine what students actually got out of the experience!

Most classes then want to compile the best individual features (optimal window placement, the most effective roof, a functional layout of deciduous trees, etc.) into a single model. Do the individual components complement each other, or can it happen that one feature actually interferes with another? These are all circumstances that designers and engineers have to deal with, and one that students are capable of grappling with in the context of a hands-on project.

Lessons Learned

When I started facilitating this program, I was glad to see that so many students in these grade bands had already been exposed in school to astronomical models and properly understood that the Sun's apparent daily motion results from the rotation of the Earth. Some students, but not all, can also explain how Earth's seasons over the course of one orbit result from its tilted axis, rather than distance from the Sun. What completely shocked me was how almost no one could actually step outside and point out the sun's path over the neighborhood in any season. I've actually had students brag, "We've got GPS navigation; you don't need to know how to get around!"

While students are learning to visualize astronomy concepts, what hasn't been happening often enough is the chance for students to apply this knowledge in a useful, real-world way. Once using their solar knowledge in a Home Design Challenge is outlined, 10 to 14 year olds are quickly engaged in the project. Some teams get mildly competitive with each other, but they also see that combining design variables may have a synergistic effect for the house model.

There can be moments of anxiety leading up to the final flashlight demonstrations. Will the windows, roof, and trees do what they're supposed to over the course of the seasons? If they do, it is not uncommon for applause and high-fives to go around the class. What better evidence of personal investment in learning can we ask for?

We've always known that children (and adults) are more interested in learning when there is something interesting to do with that knowledge. The latest formal science teaching standards do put a great emphasis on students participating actively in the processes of science, as well as applying new content to solve a problem. In a passive solar design project, students do just that – understand the predictability of the Sun, and design to use it freely for the benefit of our homes and the environment. Our children can move from the simple question, "what?" to the more complex one, "so what?" And perhaps most important, we can encourage children to think, "now what?" Working with simple models is an experience that can open children to the idea of pursuing careers in Design, Architecture, or Engineering. If we are lucky, we might even be preparing future homeowners to play their parts in making the built environment more sustainable with the natural landscape.

Susan Lewicki is the senior Environmental Educator for the Meadowlands Environment Center in northeastern New Jersey. She has over 20 years of experience developing and leading hands-on field trips for K-12 students and community groups, as well as standards- and place-based teacher workshops.

Resources

Gould, Alan. *Hot Water and Warm Homes from Sunlight.* Teacher's Guide. GEMS c/o Lawrence Hall of Science, University of California, Berkeley, 1995.

Gould, Alan, Willard, Carolyn, Pompea, Stephen. *The Real Reasons for Seasons: Sun-Earth Connections, Grades 6-8.* GEMS c/o Lawrence Hall of Science, University of California, Berkeley, 2000.

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Endnotes

1. SunPosition, "SunPosition Calculator" http://sunposition.info/sunposition/spc/locations.php