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Engaging Physics Students Using Environmental Lab Modules

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This paper discusses multi-week activity modules that use civic engagement[1] to increase student interest and learning in physics. The modules consist of a mixture of hands-on, field, and Internet-based activities that allow students to investigate their impact on the environment and to examine changes that they can make in their lifestyle to lessen this impact. Assessments of student learning and interest using the modules show that they achieved their goals.

Modules

The modules were created as part of the Environmental Science Activities for the 21st Century (ESA21) project, which has produced modules that cover the entire breadth of topics found in an environmental science course. Within this set of activities, there are whole modules that are of direct interest to a physics course, such as the ones on home energy, fossil fuels, nuclear energy, and renewable energy, and which can form the core of a physics class on energy use (see Table I). All of these modules are described in detail at http://esa21.kennesaw.edu. There are also activities within other modules that are of interest in a physics course. For instance, our ozone module (http://esa21.kennesaw.edu/ozone.htm) contains an activity concerning the amount of UV radiation from the Sun that is absorbed by stratospheric ozone, while the plate tectonics module (http://esa21.kennesaw.edu/plate.htm) includes an activity dealing with earthquakes and how sound waves travel through the Earth.

These modules are designed as multi-week sets of activities allowing students to investigate topics in greater depth. Some of the activities in the modules provide background information on basic science while others relate the material to the students' world. After evaluating their impact on the environment in the capstone activity to the module, the students consider what they could change about their lives to decrease their impact on their surroundings, and discuss the economics and likelihood of such changes.

The activities include a mixture of hands-on, field, and Internet-based experiences. The background information is usually provided through hands-on activities. The Internet exercises involve computer simulations, calculations, virtual field trips, and multimedia presentations. In some cases, alternatives to the hands-on activities are offered that allow students to do experiments at home or in the field with equipment that can be purchased commercially. This flexibility in format allows the modules to be used in a variety of settings, from traditional lab courses to online classes.

The home energy module serves as a good example of how a module is implemented. In the first activity the students identify and measure various parameters of their homes, such as the surface areas of the exterior components and the properties of the material that constitute them. The second activity is a hands-on experiment in the lab for investigating the relationship between the R-factor of various home building materials and the rate at which heat is conducted through them. In the third activity students use the data from the first exercise to estimate how much energy they are using in their homes, and finally in the capstone activ-

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Table I. Energy modules.

Module	Activity	Description
Home Energy http://esa21.kennesaw.edu/homeenergy.htm	Home Energy Audit	Measure dimensions of exterior components of home and identify materials used in construction in preparation for home energy analysis. At home.
	R-Factor	Calculate R-factor by examining the rate of heat transfer across typical materials used in home construction in hands-on activity. In lab.
	Synthesis and Analysis	Analyze home energy usage with online home energy audit calculator using data gathered in first activity. At home and online.
	Capstone	Propose and economically evaluate three improvements to home energy efficiency. Online.
Fossil Fuels http://esa21.kennesaw.edu/fossilfuels.htm	Oil	Measure the porosity and permeability of sedimentary rock analogs. In lab.
	Coal	Measure the ash/residue content of various forms of coal. In lab.
	Natural Gas	Use a computer simulation to study the process of exploration and seismic surveying. Online.
	Capstone	Calculate the amount of fossil fuels used and pollutants emitted. Online.
Nuclear Energy http://esa21.kennesaw.edu/nuclear.htm	Decay	Use a dice analog to study the relationship between half-lives and nuclear activity. In lab.
	Power Plant	Use a computer simulation to study the workings of a nuclear power plant. Online.
	Exposure	Measure the amount of radiation exposure due to various environmental and lifestyle factors. Online.
	Capstone	Compare the amount of pollution caused by student using electricity in the U.S. to that if the student lived in France. Online.
Renewable Energy http://esa21.kennesaw.edu/renewable.htm	Hydroelectric	Use a turbine generator to study the relationship between height of water and energy output. In lab.
	Solar	Study the effect of size and color on solar collector output. In lab or at home.
	Wind	Use weather data to map the relationship between isobars and wind speed/direction. Online.
	Capstone	Investigate the economics of using renewable energy in student's region. Online.

ity they evaluate the economic feasibility of making three changes to their home.

Some of the activities rely on "homegrown" materials such as the home energy analysis calculator (http://esa21.kennesaw.edu/activities/homeaudit/ homeaudit.pdf); however, most of them take advantage of excellent materials that we have located on the Internet. For example, the nuclear energy activity uses a nuclear power plant simulator (http://esa21.kennesaw.edu/activities/nukeenergy/nuke.htm) that is very easy to understand and operate. It was produced by a video game creator with a background in nuclear energy, and reduces the very complicated operation of such a unit to its bare essentials in order to help students understand the function of power plant components such as control rods and cooling pumps. Where possible, we have secured the rights to mirror these materials in order to prevent their disappearance from the web, which is a common problem with Internet activities. Our selection of web materials includes background and enrichment information related to each activity. By providing three to 10 pages of textual information before each activity, we have made these modules textbook-independent. Some of the information has been produced by the activity creator, while other information is provided by links to governmental pamphlets, databases, and research reports. All may be found at the project website given above.

Assessment

Activities from the ESA21 project were used in the second semester of a two-semester science course sequence for nonscience majors that satisfies the general education science requirement at Kennesaw State University. This second course in the sequence is a non-lab course that deals with energy. The impact of these modules on student learning has been assessed using the Student Assessment of Learning Gains[2] instrument developed by the SENCER program. Using pre- and post-surveys, this instrument measures changes in student interest in science and civic matters, as well as their perceptions of learning facilitated by the various aspects of the courses. The results show that these module activities have great promise in engaging students more strongly and in helping them explore science topics in greater depth. The modules' focus on addressing real-world problems was rated by the students as the primary factor that helped their learning in the class. We found that almost one-third of the students experienced an increase in their desire to take another science class, while a quarter expressed an increased interest in teaching science. Given the nationwide shortage of science teachers, this is a very positive sign for the use of these modules.

Work is continuing on creating new activity modules, as well as making the current activity modules more amenable to varied forms of classes. All of these modules are available through the project website. We invite teachers to visit the site, use what they can, and provide feedback on the activities that they use. We would also be happy to provide any additional information about the ESA21 project requested by interested readers.

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1. This approach is being championed by the Science Education for New Civic Engagements and Responsibilities (SENCER) program of the American Association of Colleges & Universities. See W.D. Burns, "Knowledge to make our democracy," *Liberal Educ.* **88**(4), 20 (Fall 2002).
2. J.E. Heady, "Gauging students' learning in the classroom: An assessment tool to help refine instructors' teaching techniques," *J. Coll. Sci. Teach.* **31**(3), 157–161 (Nov. 2001).

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