K-12 Energy and Environment Lessons That Work

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ABSTRACT

There are many reasons to be interested in sharing energy and environment lessons with K-12 students. These include the joy of educating students about basic energy concepts and environmental impacts. Regardless of one's motivations, having a solid planning process provides a much better opportunity for success. This article allows readers to gain an understanding of why it is important to be knowledgeable about educational learning standards which relate to energy and environmental issues. Several lessons that work for students and examples of how these lessons have been used in Virginia's Loudoun County Public Schools (LCPS) are described. Using pictures, descriptions, and a touch of imagination, readers will be able to participate in each of the lessons in a virtual way.

The LCPS's energy and environment program has offered lessons for the enrichment and extra-curricular activities of students and community members for many years. The six most successful and well developed lessons are as follows:

1. Connecting the light switch to the environment—Participants learn where energy comes from and how energy use (or non-use) impacts the environment.

2. Building audits and virtual auditing—Participants become a part of a team and they learn how their actions can make a difference.

3. Squishy circuits—Using Play Dough participants learn the basics of circuit construction as well as parallel, series and short circuits.

4. Which lamp is better?—Participants learn about life cycle cost analysis and how to measure and compare the costs of light sources.

5. The convincer—A human powered electricity generator allows people to feel for themselves the difference between the energy consumption of one light source compared to another; everyone leaves convinced.

6. Vampire hunting—Vampire electronics are everywhere, in surprising places and creating a surprising impact. These normally invisible creatures are identified and their impacts are researched—we teach students how "kill" them.

The goal of this article is to share how these lessons were developed, how they have been executed and received by various audiences and how others could potentially offer similar lessons in K-12 communities.

BEFORE GOING TO A SCHOOL

Perhaps you have a great idea, a desire to share it, and want to change the world by educating the leaders of tomorrow. You believe that if you can get the information to the schools it will be life changing. All that may be true but don't go to a school without considering the following: while you may be a subject matter expert, it is unlikely that you really know how a school works. Today's schools are not the same as you remember them to be from the days of your youth. To be successful in bringing information to the schools and sharing your knowledge with students it is important to understand curriculum guidelines.

Depending on the school, curriculum guidelines have different names and are administered by different agencies. Essentially, those paying for the schools want to ensure that curriculums meet minimum standards regarding what students learn. Learning expectations are documented and the curriculums are somewhat standardized. You might ask yourself: Why does this matter to me? Why would anyone not want me, a well-known expert, to share my knowledge with them? I understand this thought process. It does seem like an obvious benefit to the schools and students, but from their viewpoint it may be more difficult to understand.

Schools are under pressure to meet the standards described in their curriculum guidelines. Activities that are not directly connected to the goals of the standards which govern the operation of the school may not be positively received; if it's not a "must have" it's a "nice to have." You first must determine how the information you want to present correlates to the curriculum guidelines. To do this you must know what the curriculum states.

Do the research, find out what is required and make sure you are offering something valuable that meets the needs of the school. This first step is essential for success. No one cares how much you know until they know how much you care. Learning about the curriculum and showing how the knowledge you offer to share fits goes a long way to show people that you care.

Working with Curriculum Guidelines

On-line research helps identify the curriculum requirements for the schools you are interested in working with. However, if you are unable to locate what you need, try calling the district offices to ask where the cur-riculum can be found. When you have the curriculum available, look for the section on science. You will likely need to look at various grade levels and various subjects to find exactly what you require.

Energy topics will appear, environmental literacy topics may also be found. You may need to be imaginative to explain how the informa-tion you want to present connects to the curriculum. It doesn't always have to directly correlate, but there needs to be a clear connection to the content and competencies described. The content you plan to present doesn't necessarily need to be designed for the curriculum's grade level. While it may not be a perfect match, your efforts will demonstrate that you learned what was important to the school and that your informa-tion is pertinent to some part of the required curriculum. It will build good will and interest in any further information you may want to provide.

Linking Ideas to the Curriculum

Next, I will discuss the process that was used when the team I work with first considered offering instructional opportunities to stu-dents. We knew that if we didn't directly support the curriculum, we were not going to be received positively. We set out to determine how energy management might fit in. In addition to being a certified energy manager, I am also a licensed teacher in Virginia with ten years of class-room experience. I understood the importance of connecting our ideas to the required curriculum.

We used an internet search to find the standards of learning for the Commonwealth of Virginia. We identified twelve sections of standards with over fifty different areas of interest related to energy and the environment (see http://tinyurl.com/LCPS-SOL for the complete list). In our lesson titled "Connecting the Light Switch to the Environment" we address segments of the learning standards. Here are examples:

SCI 6.2 The student will investigate and understand basic sources of energy, their origins, transformations, and uses. Key concepts include:

a) potential and kinetic energy;

b) the role of the sun in the formation of most energy sources on Earth;

c) nonrenewable energy sources (fossil fuels including petroleum, natural gas, and coal);

d) renewable energy sources (wood, wind, hydro, geothermal, tidal, and solar); and

e) energy transformations (heat/light to mechanical, chemical, and electrical energy).

The focus of the lesson is for students to understand how energy production of both fossil fuels and renewables directly impact the environment. It is not difficult to connect this concept to the science standard of learning in this case. However, it is not always obvious. In our lesson titled "Building Audits and Virtual Auditing" we address the following standards:

SCIK.10 The student will investigate and understand that materials can be reused, recycled, and conserved. Key concepts include:

a) materials and objects can be used over and over again;
b) everyday materials can be recycled; and
c) water and energy conservation at home and in school helps preserve resources for future use.

SCI 1.8 The student will investigate and understand that natural resources are limited. Key concepts include:

a) identification of natural resources (plants and animals, water, air, land, minerals, forests and soil);

b) factors that affect air and water quality; and

c) recycling, reusing, and reducing consumption of natural resources.

In this case the concepts of energy conservation and reducing consumption are stated. It takes an individual who is willing to consider a small component of a standard and extend it to include building energy audits. However, this is exactly the type of specialized knowledge that a classroom teacher often lacks. In addition, energy auditing can be a hands-on or virtual experience which allows for many learning styles and classroom situations to be included. The best lessons are those that offer a unique perspective and clearly connect with and logically support a learning standard.

Which Came First, the Standard or the Lesson?

Throughout the remainder of this article, the standards that are addressed by each lesson are not shown. Each school district has different learning standards. Perhaps you have an idea and just needed an audience. Sometimes, it's the other way around. You may have an audience and need an idea. The standards can be used both ways. If you need an idea, read through the standards and ask yourself a few questions. How does what I know relate to these standards? How can I safely and effectively demonstrate this to students? What activities can I provide for students to engage active participation? When you have answers to these questions, you will be on your way to successful lesson planning.

It could be possible that you find yourself bringing information to students without having an intrinsic interest in doing so. Perhaps you were solicited by a parent-teacher association, or one of your children's teachers. Your best results will occur if you make a plan and connect the lessons to your local curriculum standards. This article will present workable ideas. Use them and make them our own—either in their entirety or choose the parts you like best.

THE LESSONS

In this section I offer a set of sample energy lessons with examples of how they have been used in LCPS. The goal is not only to share how these lessons were executed and received by various audiences, but also to inspire others to offer similar lessons in K-12 schools and communities.

Connecting the Light Switch to the Environment

In this lesson participants learn where energy comes from and how energy use (or non-use) impacts the environment. We begin this lesson by reviewing information provided by the United States Energy Information Agency (USEIA) which shows how electricity has been generated in the U.S. (Figure 1).

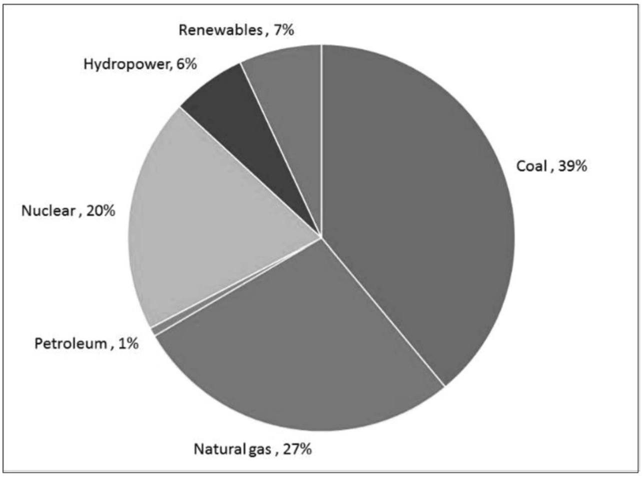

Figure 1. 2014 U.S. Electricity generation (USEIA).

Once students learn that coal is the single largest fuel source for electricity generation in the U.S., we then discuss how coal is used to generate electricity. We found an excellent video produced by one of our local electricity providers. The video discusses how coal-fired power plants work and details the entire process (see http://tinyurl.com/hrht76c). Students are asked to look for specific steps in the process—coal being delivered, conveyors moving coal, a pulverizer turning coal to powder, a boiler burning coal, water going through pipes and changing to steam, steam turning a turbine, a turbine turning a generator, and electricity being produced and distributed. As part of a group participation activity, students are asked to act out the entire coal fired power plant electricity generation process. We have the students use hand and body movements and create sounds. Through this, they learn and remember. Regardless of the students' age or group size, they all enjoy this acting out process.

Upon completion of the acting process, we then show students where coal comes from. We show underground mines, pit mines, strip mines, and mountaintop removal mines. The pictures are an eye-opener for most students. We never vilify coal producers or criticize their operations, we simply state the facts and let students form their own opinions. We point out that we need coal mines since we all use energy. In 2016, 30.4% of our electricity was produced by coal combustion. The students were among those who asked companies (indirectly) to mine coal because it was needed for electricity generation.

While we often close the lesson here, there are extensions available. It is possible to discuss renewables or non-renewable energy sources. Environmental issues such as emissions from coal power plants can be discussed. It is possible to talk about nitrous oxides, sulfur oxides, carbon oxides, particulates and other emissions. Offering general information regarding emissions control devices and the methods used by electricity generators to reduce environmental impacts is another option. Research regarding clean coal and sequestration might be discussed. While the topic is open-ended, time may be limited and it is wise to offer a strong conclusion for the lesson.

Building Audits and Virtual Auditing

In this lesson, participants form teams and learn how their actions can make a difference. Those in the field of energy management understand building energy audits. An energy auditor (or audit team) assesses a building, its systems, equipment operation and recommend ways to reduce the energy use and operating costs of the building. There is a broad range of information that might be considered—the assessment can be limited in scope or include an immense amount of detail.

For schools, we focus on showing students how their school building works, highlighting actions and activities that teachers, students, and staff can impact. Probably the most important decision for the instructional leader when considering how to implement this lesson is student behavior. Safety is a primary concern. If students follow directions, walking through a mechanical room or an electrical room is not dangerous (Figure 2). However, if students are involved in horseplay or will not follow directions, someone could be hurt.

Figure 2. Light fixture survey underway.

If students can be relied upon to exhibit good behavior, you might consider walking them through the school. Access to spaces must be provided which requires coordination with the administration. The instructional leader will need to become familiar with the building prior to touring the building. Performing an actual building energy audit while students walk through the school is challenging yet possible. It is important to keep two categories of issues in mind. The first includes opportunities which are more common and less interesting, yet within a student's sphere of control. These include keeping windows closed, turning off lights and computers, and reporting equipment that is not functioning properly. The second category includes opportunities which are interesting to students, but beyond their sphere of control. These include making changes to controls, boilers and chillers or replac-

Figure 3. Student viewing the boiler fire tube through the sight glass.

Figure 4. Students viewing building automation circuitry.

ing lighting systems (see Figures 3 and 4).

I recommend that students be exposed to as many building systems and components as possible with greater attention to opportunities for students to have a direct impact. While it is fascinating to understand how variable frequency drives change the speed of pump motors or how building automation circuitry controls equipment, students may be unable to apply this. Knowing the number of computers or light fixtures in a room provides information that can cause students to act.

A successful lesson requires explanation, a few simple calculations, and a bit of motivation for students to use their ideas to help their school reduce its energy use, costs and environmental impacts. Students often feel unempowered to take simple actions such as turning lights off in an empty classroom. Why not allow students to assist with efforts to reduce energy while they learn about the concepts?

As the instructional leader you might be asking yourself: What if I'm not confident in student behavior? What if I need to show them something on the roof? What if I have no access to the building other than the space in which I will be presenting to students? These concerns are surmountable. You might consider a virtual assessment. There are examples of virtual energy audits that can be used such as the webinar entitled "Capturing Efficiency—Conducting Audits in Commercial Buildings with Energy Star" (see http://tinyurl.com/VirtualAudit).

You will need to gather some images and examples of energy audits you have performed in the past, or use a virtual audit as an example. By showing the pictures and providing explanations, participant safety is assured. Be sure to use examples that can be identified as part of an audit, showing places you would not take a group students. This is safest and best approach for anyone new to working with K-12 students. Whether you perform an actual audit, a virtual audit, or a combination of the two, don't miss the opportunity to educate students, motivating them to make energy conservation decisions and take energy savings actions.

Squishy Circuits

Is Play Dough an insulator or a conductor? This question begins this lesson. Depending on the age group, we sometimes need to define those terms. Knowing their definitions likely appears in a section of the curriculum guide which governs what is taught in most schools. By using technical terminology, we let students know that serious learning is about to happen. Students are surprised to discover they will be using Play Dough to learn the basics of circuit construction as well as parallel, series, and short circuits. For those unable to handle the suspense—Play Dough is a conductor.

When working with students it is important to explain how circuits work. Describing electricity's route from the battery, through a conductor, to an energy using device (like a lamp), back through a conductor, and returning to the battery is essential. While presenting this information to students I ask students to use their circuit tracer (pointer finger) and follow the circuit with me, one circuit component at a time. This is the way to teach basic circuits.

For our demonstrations, we use very simple materials. We provide each student or pair of students with a battery, terminal wires, light emitting diode (LED) lights and some Play Dough. Certainly, a motor, a sound maker, or other energy using device could be included, additional conductors added, or switches placed in the circuit (Figure 5). Anything possible with wires is possible with Play Dough. By using simple examples, we are applying one of the most important engineering rules—keep it simple. The concepts are not complicated and have widespread appeal.

For the intrepid there are an amazing number of extension possibilities for this lesson. A meter could be placed on the circuit and the resistance of the Play Dough could be calculated from the measurements; a circuit controller with multiple functions could be included with all Play Dough wiring. Just remember to build on the foundation of basic circuitry while keeping the cognitive level of your audience in mind. The unexpected fun from using this lesson creates memorable experiences and wonderful learning opportunities.

Figure 5. High school students making squishy circuits.

Which Lamp Is Better?

This lesson focuses on the basics of life cycle cost analysis. Incandescent, compact fluorescent, and LED lamps (each of the similar color temperature and lumen output levels) are compared to determine which is best. Students learn that initial cost is not the only variable to assess when considering an energy conservation measure. By learning how to compare the costs of one lighting source compared to another and performing the calculations themselves, students become acquainted with the type of work performed energy engineers.

Since we are comparing lighting, truly complex calculations that would be involved if comparing building envelope changes, HVAC equipment, or motors are not required. Regardless, students must apply their math skills and use a worksheet (Figure 6). Students take measurements and perform on-line research using the most current information available.

Since students perform the research, they do not rely on the instructional leader for answers. Instead they learn the methodologies for determining the answers. The calculation process can be performed in many ways. Be sure to explain the process using logical steps. Work with the students to successfully make progress on each step before determining to the solution.

The lesson plan includes comparing lamps which advertise similar

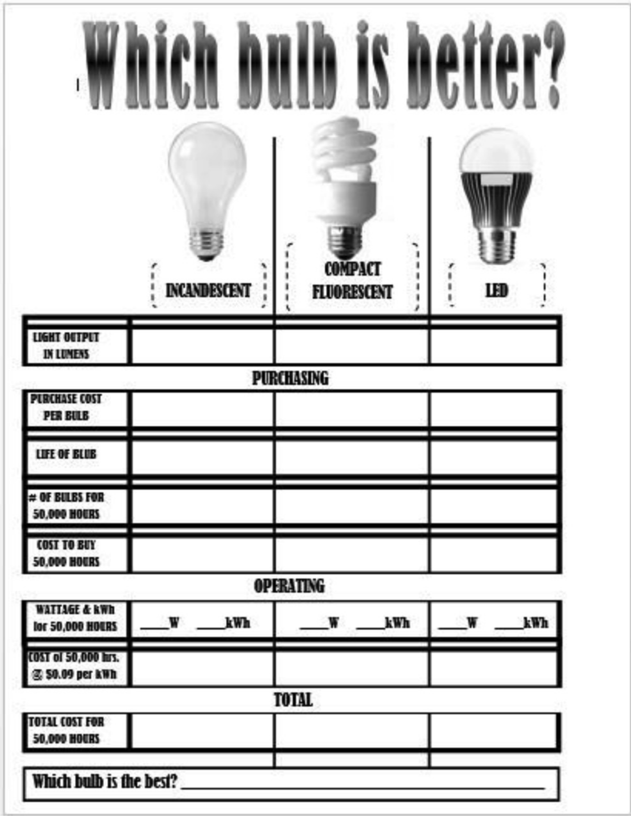

Figure 6. Sample worksheet for lamp cost comparisons.

lumen output. It is important to obtain lamps that are equal in light output and color temperature. We explain light output and define lumen. We also discuss color temperature, sometimes showing a lamp with a different color temperature. We highlight how ignorance of a lamp's characteristics might cause some to be negatively inclined towards a technology when the issue was that they did not understand how it worked. By setting expectations and explaining options, we ensure that students know how to make reasonable comparisons.

We begin with measuring the light output of the lamps. Not being in a laboratory setting there are likely light sources in addition to the lamp. We use a hand-held light meter and work with the students who are likely using a light meter for the very first time. These factors are important since the light output readings are likely inexact. We ask students to allow for a 10% to 15% variance in light output.

Next considered is the cost of the lamps. One approach is to simply show receipts and let students see the purchase prices. Another approach is to ask the students to work in teams and find lamp prices on the internet. Create a friendly competition to determine who can find the best prices for lamps with characteristics similar to those needed for comparison. For this, the lamp manufacturer is less important than the lamp's light output and color temperature.

The next step is to normalize the initial purchase cost based on the life expectancy of the lamps. While the life of lamps cannot be directly measured, we can look at the packaging and use the manufacturer's claims as the basis for our calculations. Once the operating life for each lamp is determined, baselining to a certain number of hours (perhaps 50,000) is the best approach. How many lamps are needed for a given number of hours of light? Multiply that by the lamp's initial cost and the purchase cost of the lamps is normalized. Students are often surprised when they determine that the incandescent lamp is no longer a viable option after an initial cost normalization.

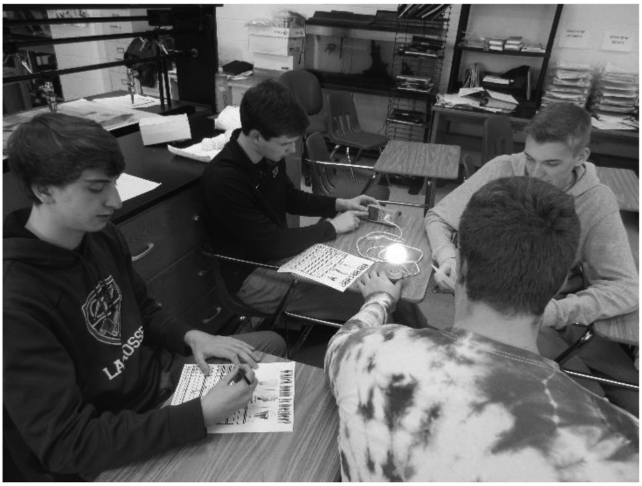

Figure 7. Students using a watt meter.

Next we consider the lamp's operational costs. A watt meter is required to take measurements. Students learn to do this with very little instruction. Since consumers are not billed based on watts, we use this opportunity to explain units of measurement, conversions and kilowatt hours. We ask students to take the number of watts, multiply by 50,000 hours, then divide by 1,000 to obtain kilowatt hours. The cost of operating the lamps can then be determined.

We finish the comparison reminding students that they must combine the initial purchase and operational costs together to estimate the total lifecycle costs. When this is complete, we ask students to tell us what they learned based on their research. The overwhelming response is that the LED lamp is the best. We then ask students to share the information with their families and challenge them to change at least one lamp in their home to a LED.

The Convincer

In this lesson, we use a human powered electricity generator which allows students to feel for themselves the different energy requirements needed for incandescent, compact fluorescent and LED lamps. The cost for the materials required for this lesson may be prohibitive. LCPS received a cash award from the school boards association when our district won the 2011 "Green Schools Challenge." Our district used these funds to purchase two human powered generators.

The convincer is a device which allows a person to feel the difference in energy required by the different technologies (Figure 8). Using the convincer, students do not need to rely on research, the word of a teacher, or a watt meter. The convincer requires the student's physical energy to illuminate the lamps. Because of the way students experience the energy needs of each lamp, they do not forget it. Most students never fully illuminate the incandescent lamps. When they try the compact fluorescent lamp, most can light it, but it requires a consistent effort and speed to maintain the illumination. Perhaps my most satisfying experience as an educator is watching the reactions of participants in convincer demonstrations as they easily turn the handle to illuminate an LED lamp— fascination, wonder, amazement and disbelief. When they try the LED lamp, they are surprised to discover that they can light it with just two fingers lightly holding one handle.

The convincer is used teach the basic concepts from "Which Lamp is Better." The difference is that the calculations can be avoided. Using the convincer, the time is spent making sure that each student has an opportunity to be the power generator.

A few words of caution—the generator system will almost certainly be a twelve-volt direct current (DC) system which requires the use of appropriate lamps. It is important to never allow anyone to

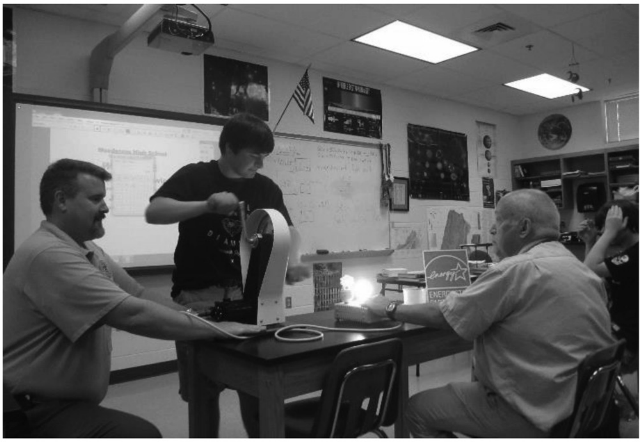

Figure 8. The Convincer used for a high school demonstration

place a DC powered bulb into an alternating current (AC) powered socket. The lamp will be destroyed. The convincer is not a tool for the very small people of the world who are not strong enough to turn the handles. A certain arm length is required to avoid being hit in the face as the handles are turned. Although they may not be able to directly participate, they can watch, cheer and learn the concepts of the lesson.

Figure 9. Measuring the vampire's energy usage.

Hunting Energy Vampires

What is an energy vampire? They are energy consuming devices that can be turned off but continue to consume energy when plugged into a power source. Vampire electronics are everywhere. In this lesson, these normally invisible “creatures” are identified, their impacts are researched and students learn how to “kill” them.

To make this lesson more successful, we bring a collection of energy vampires with us. However, it is possible to simply look for them in whatever space you may be using. While I do not recommend the latter approach, feel free to measure items in the classroom, but bring some items with you as well. There are devices which use no energy when turned off, like lamps, toasters and space heaters (so long as they have no display lights or screens).

Students will need to use a watt meter to measure the energy consumption of the various devices. The device should be turned on and then turned off. Students will expect the meter to go to zero when the device is turned off—it will not. Have the students note the wattage they measured. At this point, we explain that a surge protector with an off switch will cause energy vampires to stop using energy. We unplug the device from the socket or extension cord and plug it into a surge protector. Once the surge protector is switched off, the meter drops to zero. We make it fun and call it vampire hunting. Our advice to students: “Go out and kill a few vampires. It will be fun and save energy too.”

Next, we explain why killing energy vampires is a valuable pastime. We ask students to refer to their noted measurement of the energy used by the vampire and explain how we can readily determine what it costs to have the device plugged in for a year. The calculation is simply device wattage multiplied by 8,760 (number of hours in a year) divided by 1,000W/kWh, yielding the result in total kilowatt hours. Then the student simply multiplies the kilowatt hours by the average cost per kilowatt hour. For most devices, the costs may not be substantial—unless a large appliance such as a plasma television is used as an example.

Once a single device has been identified and measured, the students can measure all kinds of devices. The only variable is the amount of energy that each device consumes when it is ostensibly turned off. The first calculation should be done as a group effort but subsequent measurements and calculations should be performed entirely by the students. Check with them, make sure that everything is being done properly, but don’t do it for them.

Special cases that are notable included cell phones, iPads, or similar device chargers. Individually, these transformers use less than one watt when no device is plugged in. A basic watt meter will probably not be sensitive enough to register the energy use of a single charger. However, when four or five are combined, the total consumption reaches an amount that can be registered. A one watt device (or group of devices) left on for an entire year at a cost of $0.10 per kilowatt hour will cost only $0.88 annually. However, there is usually more than a total of one watt of vampires in a student's home.

We ask students to consider devices that may be plugged into guest room, basement, garage, or kitchen outlets. Eventually, students will have a list of energy consumption and costs for a variety of energy consuming devices. They can use this list to estimate the energy costs for vampire electronics in their home. It is amazing the numbers that we have seen. Some homes have as much as 200 watts of energy vampires. That means their family could be feeding vampires at a cost of $175 a year!

After all the measurements and calculations are completed, we ask students to consider how else their family might spend the money that currently feeds their energy vampires. The idea that a student may be missing out on a trip to the movies, a new game, or some other item of interest tends to get their attention. As with all the other lessons, we invite students to actively reduce their energy use, costs and environmental impacts. In this case, they may be able to reap the benefits.

SUMMARY AND CONCLUSIONS

The lessons I have described in this article are designed to support local curriculum guidelines. The lessons present pertinent energy and environmental information that may not be covered in similar ways during normal classroom time with most teachers. The lessons are fun, thought provoking, interactive, educational, and offer numerous opportunities for student participation. It is important to recognize that lessons used in classrooms must support the principal, teachers, and instructional goals of the school. These professionals are the primary instructional leaders. If you proceed with this in mind, I am confident you will do well. Please let me know how it works for you.

ABOUT THE AUTHOR

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Mr. Lord currently serves as the president of the National Capital Chapter of the Association of Energy Engineers. In addition, he serves on the Metropolitan Washington Council of Government's Climate, Energy and Environmental Policy Committee. Due in part to the efforts of this team, LCPS won first place in the Virginia School Boards Association's 2011 Green Schools Challenge and has earned the energy star partner of the year awards for 2010—2016. Email: john.lord@lcps.org.