When Batteries Die,
Do They Go to Heaven?

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Overview

The US Environmental Protection Agency (2015) estimates that 254 million tons of solid waste is produced in the United States each year. How much is that for every person in America? About 4.4 pounds *every day* for every man, woman, and child![1] And this estimate does not include the stuff we flush down the toilet. Where does all this waste end up? Often, the answer is a landfill.

Consider batteries alone. According to the Everyday-Green web site, "each year Americans throw away more than three billion batteries. That's about 180,000 tons of batteries. More than 86,000 tons of these are single use alkaline batteries…[a]bout 14,000 tons of rechargeable batteries are thrown away in the United States."

Unlike most of the trash that winds up in a landfill, batteries are hazardous waste. They contain a number of heavy metals, such as mercury, nickel, cadmium, and lead, which can pose significant health risks. Batteries also contain corrosive materials.

This unit will address the question of what waste is by examining the materials in the batteries we "throw away" and will consider alternatives to disposal in a landfill.

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[1] Assuming a U.S. population of 318 million:

$$\frac{\frac{\text{254 million tons}}{\text{1 year}} \times \frac{\text{2000 lbs}}{\text{1 ton}}}{\text{318 million persons}} \times \frac{\text{1 year}}{\text{365 days}}$$

Rationale

It is a simple application of the Law of Conservation of Mass: you cannot get rid of anything. This concept is regularly taught in science classes but often fails to be internalized by students...or the population at large. So, what happens to the stuff we throw away? Out of sight is out of mind, so why should we be concerned? Consider the following claims: Much of our waste is toxic. Landfills are running out of space. Landfills leak and are contaminating the environment. Incineration produces even more toxic waste and is unregulated. Only a fraction of recyclable materials is being recycled. We produce too much waste as it is, and the amount is increasing.

One goal of this unit is to enable students to identify resources that they will use as they investigate the problem of waste generation and removal. In particular,
I am interested in aspects of the problem that are especially local in scope and upon which students may have an immediate impact. For example, the School District of Philadelphia has not implemented procedures for the collection of recyclables, and much of these materials wind up in the trash. Additionally, the proliferation of personal electronic devices (notably, Smartphones) and the regular replacement underscore the need for an understanding of the "lifecycle" of materials and the consequences of indiscriminate disposal methods.

Objectives

Students will be able to

- examine the types and quantity of materials that are classified as waste on a local, regional, national, and global basis,
- compare the methods by which waste materials are handled,
- predict trends in the production of waste materials,
- consider alternatives to landfills, such as incineration, recycling, and waste reduction, and
- disseminate information by means of videos and/or a web site aimed at education and advocacy.

Strategies

This unit will be inquiry-based. The characteristics of the topic lend themselves well to this approach. It involves a real world problem that is open-ended, and it is student-centered. Students will help to define the scope of the problem and will generate a list of questions that focus on the important aspects and applications of the problem. Furthermore, they will work in teams to resolve issues and achieve the overall learning objectives while each student performs a particular role in the team. Student performance will be determined by the team members and by self-assessment using questionnaires and rubrics. For examples, see http://bie.org/objects/cat/rubrics and http://bie.org/objects/cat/student_handouts.

Classroom Activities/Lesson Plans

What is trash?

Overview
Students will examine the contents of a bag of trash from a classroom. Students will produce two charts that identify which items are recyclable and which ones are not. They will make measurements of mass and volume (compressed and uncompressed) in order to determine how much space in a landfill the trash might take up, and then they will extrapolate to estimate how much trash the school produces each day.

Materials
- a bag of trash
- a scale for weighing
- meter sticks and/or rulers

Procedure
1. The teacher may use an actual bag of trash collected in the classroom or gather items to place in a trash bag. Such items should contain a mix of recyclable items (such as drinks bottles, aluminum cans, paper, etc.) and non-recyclable items (such as Styrofoam containers, food wrappers, etc.)
2. Have students predict how much of the bag's contents is trash that needs to go to the landfill and how much might be recyclable.
3. Remove items from the trash bag one at a time. Examine each item to determine how it should be classified.
4. Have students make measurements in order to estimate the mass and volume of trash in the bag.
5. Ask students to brainstorm how they can extrapolate to estimate the amount of trash collected each day.

Discussion
Students should discuss how much of a typical trash bag might be recyclable and should be encouraged to think of other ways to handle the items found. The three R’s of waste management should be considered: Reduce, Reuse, and Recycle. The EPA provides a number of resources for students and educators on this topic at https://www.epa.gov/recycle.

Follow-up

An interesting follow-up activity, although geared to a younger audience, has students "design, build, and test" a landfill (see Teach Engineering, 2010). Students will take a field trip to a nearby landfill[2] and/or recyclable materials processing plant[3].

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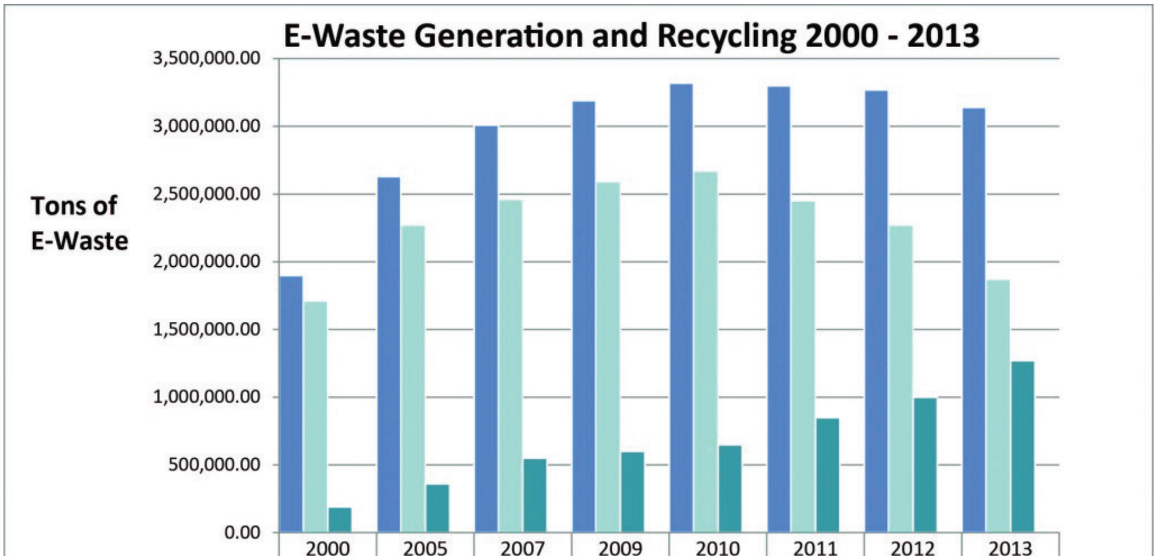
[2] One landfill facility in the Philadelphia area that encourages tours is run by J.P. Mascaro & Sons < http://www.jpmascaro.com/green-initiatives/community-tours.aspx>.

[3] Waste Management, Inc. recently opened a state-of-the-art material recovery facility in northeast Philadelphia to process single-stream recycling for the region. A promotional video of the operation is available online (https://www.youtube.com/watch?v=yl1auc_MluQ).

What is E-waste?

Overview

In the U.S., E-waste represents 2% (by weight) of the trash in landfills but 70% of the toxic waste.[4] Recycling of E-waste has reduced the amount winding up in landfills. Still, "about 60% of discarded electronics end up in the trash"[5].



	2000	2005	2007	2009	2010	2011	2012	2013
Total e-waste generated	1,900,000	2,630,000	3,010,000	3,190,000	3,320,000	3,300,000	3,270,000	3,140,000
E-waste trashed	1,710,000	2,270,000	2,460,000	2,590,000	2,670,000	2,450,000	2,270,000	1,870,000
E-waste recycled	190,000	360,000	550,000	600,000	650,000	850,000	1,000,000	1,270,000
Percent Recycled	10.0%	13.7%	18.3%	18.8%	19.6%	25.8%	30.60%	40.40%

Source:
http://www.electronicstakeback.com/ designed-for-the-dump/e-waste-in-landfills/

Not all E-waste is toxic. It is widely noted that because "cell phones and other electronic items contain high amounts of precious metals like gold or silver – each year, we dump cell phones containing worth over $60 million in gold and silver."[6]

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[4] Slade, G. (2007, March/April). iWaste. *Mother Jones.* < http://www.motherjones.com/environment/2007/03/iwaste>.

[5] Electronics TakeBack Coalition. (2015). E-Waste In Landfills: More E-Waste is Trashed Than Recycled, But Recycling Is Growing < http://www.electronicstakeback.com/ designed-for-the-dump/e-waste-in-landfills/>.

[6] Voakes, G. (2012, October 12). The Lesser-Known Facts About E-Waste Recycling. *Business Insider* < http://www.businessinsider.com/the-lesser-known-facts-about-e-waste-recycling-2012-10>.

In this activity, students will examine the problem of E-waste, starting from their reflection on the types of electronic devices that they personally use and what happens to these items after they are done with using them. Then, students will examine a series of statements about the extent of E-waste in the U.S. and around the world (*e.g.,* see *20 Staggering E-Waste Facts* below). They will select one of these "facts" and find verification from a reputable source. In a later activity, students will produce an infographic illustrating the information.

Materials

- projector
- computers with Internet access

Procedure

1. The teacher will lead a discussion about all of the electronic devices that they use every day. How many do they have? How long do they plan to keep using them? What did they do with the devices they no longer use?
2. The teacher will show Annie Leonard's video, *The Story of Electronics*, available online at https://www.youtube.com/watch?v=sW_7i6T_H78.
3. The class will discuss their thoughts about the video. How many of the devices they use were, as the video describes them, "designed for the dump"? What is the impact of disposing electronic devices in a landfill?
4. The class will view two videos on how E-waste is handled in the U.S. and overseas. *How Computers and Electronics are Recycled* (available online at https://www.youtube.com/watch?v=Iw4g6H7alvo) showcases Sims Recycling Solutions, an international electronics recycling company that, according to their Facebook page[7], processes over 500,000 tonnes of E-waste each year. In contrast, a CNN video, *Where your used electronics go in China* (available online at http://www.cnn.com/2013/05/30/world/asia/china-electronic-waste-e-waste/) cites a UN study which reported that "about 70% of electronic waste globally generated ended up in China." Similar videos are available on YouTube about the shipping of E-waste to India and Ghana.
5. Students will be presented with a list of statements about E-waste and will be asked to find confirmation of the facts from a reputable source.

Discussion

This activity introduces students to the scope of the problem of electronic waste and presents multiple perspectives on the handling of E-waste. The list of "facts" about E-waste is reproduced from the Earth911 web site. Additional *Facts and Figures on E-Waste and Recycling* are available from the Electronics TakeBack Coalition (2016) and DoSomething.org.[8]

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[7] https://www.facebook.com/SimsRecyclingSolutions

[8] https://www.dosomething.org/us/facts/11-facts-about-e-waste

As students seek confirmation of the information contained in their "fact", they will need to consider the reliability of their sources. There are several good introductory guides on evaluating Internet sites. For example, one, from the University of Illinois[9], asks students, "How did you find the website?" Often, in response to a question on their sources, students will reply, "Google" or Wikipedia. As the guide points out, "the accuracy and/or quality of information located via a search engine will vary greatly." In the guide, students are asked to also examine the web site's domain for clues on credibility as well as other indicators such as *Authority*, *Currency*, *Functionality*, *Accuracy* and *Objectivity*. It is doubtless that students will need practice on this topic, which could be a lesson in and of itself.

Follow-up

Two of the succeeding activities will ask students to perform calculations in order to check the veracity of the statements and to create and present an infographic.

[9] http://www.library.illinois.edu/ugl/howdoi/webeval.html

20 Staggering E-Waste Facts

1. The United States produces more e-waste annually than any other country. The amount of electronics that Americans throw away every year? 9.4 million tons.
2. Recycling one million laptops saves the energy equivalent to the electricity used by 3,657 U.S. homes in a year, according to the EPA.
3. For every one million cell phones that are recycled, the EPA states that 35,274 lbs of copper, 772 lbs of silver, 75 lbs of gold, and 33 lbs of palladium can be recovered. For those not familiar with palladium, palladium is a precious metal using [sic] for making electrical contacts, as well as surgical instruments and parts for watches.
4. Only 12.5% of e-waste is recycled, according to the EPA.
5. Based on e-waste disposal rates, Americans throw out phones containing over $60 million in gold and/or silver every year.
6. Recycling circuit boards can be more valuable than mining for ore! One ton of circuit boards is estimated to contain 40-800 times more gold than one metric ton of ore. There is 30-40 times more copper in a ton of circuit boards that can be mined from one metric ton of ore.
7. According to the United Nations, 20-50 million metric tons of e-waste are discarded every year.
8. Old television sets as well as CRT (cathode ray tube) monitors contain approximately 4-8 pounds of lead, a neurotoxin. Improper disposal means this toxic substance can leach into the ground.
9. It takes 530 lbs of fossil fuel, 48 lbs of chemicals, and 1.5 tons of water to manufacture one computer and monitor, according to the Electronics TakeBack Coalition.
10. In 2014, 41.8 million metric tons of e-waste was shipped to developing countries, creating not only a dumping problem in those countries, but also utilizing resources to transport the waste to countries around the world.
11. Guiyu, China is a major dumping ground for e-waste from the United States. After the e-waste is transported over to China, the electronics are dumped in the town where it litters the streets and poisons the residents. Hydrochloric acid is thrown on the items to reveal the steel and copper to be reused. High levels of lead have been reported among residents.
12. Not all e-waste recyclers are the same. There are safer ways to recycle e-waste, and then there are companies that simply export the waste to developing countries. Rather than monitoring the recycling of the e-waste for health and human safety standards in these developing countries, many businesses simply have residents disassemble waste and use scrap metal, exposing the workers to toxic materials. Look for an e-waste recycling company that has been vetted through e-stewards.org.
13. It is estimated that only 29% of global e-waste is handled via the accepted best practice recycling channels.
14. Plastics in e-waste can be recycled into garden furniture. Battery components can be reused in other batteries. Metals can be used in jewelry and automotive parts.

15. It is estimated that 40% of the heavy metals in U.S. landfills come from discarded electronics, according to Jonas Allen, Director of Marketing for EPEAT, a global green electronic rating system.
16. According to Allen, if the recycling rates for gold (15%), silver (15%) and platinum (5%) all increased to 100%, the electronics sector could realize $12 billion in financial and natural capital benefits.
17. Approximately 350,000 mobile phones are disposed of each day, according to 2010 figures from the EPA. That equates to more than 152 million phones thrown away in one year.
18. There are more mobile phones in existence than there are number of people living on Earth. Based on the number of active SIM cards in use, there are more than 7.2 billion mobile devices being used, while there are less than 7.2 billion people on the planet. The growth rate of mobile devices compared to the population growth rate is five times greater.
19. The UN University estimates that global e-waste volumes could increase by as much as 33% between 2013-2017.
20. Many major retailers will take e-waste for recycling, regardless of whether you purchased the product from the retailer or not. Among those stores accepting drop-offs are Staples, Verizon, and Best Buy. Always call ahead of time to confirm that stores will accept e-waste and what types of products they will recycle.

Source:
http://earth911.com/eco-tech/20-e-waste-facts/

Battery Science

Overview

The heart of most portable electronic devices is a battery. There are a wide variety of battery types, but essentially, in a battery, chemical potential energy is converted into electrical energy. There is also a plethora of information on how to make a battery using simple materials. One easy example involves electrodes made from two dissimilar metals (*e.g.*, two different types of coins, a piece of copper wire and a piece of aluminum wire, etc.) and uses a lemon, cola, or even salt water as an electrolyte. There are literally scores of videos demonstrating this technique.

More advanced batteries can be derived from aluminum and air (*e.g.*, http://www.instructables.com/ id/Aluminum-Can-Saltwater-and-Charcoal-Battery/ or http://www.exploratorium.edu/files/teacher_institute/ downloads/Al-air.pdf), zinc and carbon (https://melscience.com/en/experiments/ zinc-carbon-battery/), and even mud (http://www.instructables.com/id/An-Easy-Cheap-Soil-based-Microbial-Fuel-Cell/). There are also kits readily available from MelScience.com, IASCO-TESCO.com, Mudwatt.com, and other companies.

In this activity, students will test different electrode materials using lemons and measure the voltage produced using a digital multimeter. Then, they will select a battery described on Instructables.com or another web site, build, and test the battery they produce.

Materials

- lemons
- various metal items to be used as electrodes (e.g., iron nails, galvanized nails, aluminum nails or wire, copper nails or wire, magnesium ribbon, etc.)
- digital multimeters with probes[10]

Procedure

1. The teacher will show the video, *How to Make a Lemon Battery* (available online at https://www.youtube.com/watch?v=GhbuhT1GDpI).
2. Students will create a data table to record the voltages produced by various combinations of metal electrodes and graph their results. Then, they will test each pairs of metals.
3. The teacher will show *How It's Made* videos on *Alkaline Batteries* (available at https://www.youtube.com/watch?v=ksxSOwA933M) and *Lithium Ion Batteries* (https://www.youtube.com/watch?v=HJrNCjVS0gk).
4. Students will research alternate battery designs online and make a proposal for the type of battery they will build.

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[10] Inexpensive but serviceable multimeters are available from Harbor Freight for $5.99 (and sometimes even less).

5. Students will build a battery, documenting their work with photographs and text that will be posted on their Google drive account.
6. Upon completion, students will demonstrate and present their battery to the class.

Discussion
This is a relatively simple activity, but care must be taken that students do not attempt anything that is dangerous, expensive, or time-consuming.

There are several interesting videos that describe how batteries are recycled available online. One, *Why Can't You Throw Away Batteries?* (available at https://www.youtube.com/watch?v=sdAme_Nw7qM) is notable in that it is rife with factual errors. For instance, the video discusses alkaline batteries but talks about recycling lead and neutralizing acid. Another video (available at https://www.youtube.com/watch?v=CLXOngR2gRU) illustrates the process of recycling alkaline batteries but has no narration. A longer (almost 26 minutes) video (available at https://www.youtube.com/watch?v=lMn-sDvgj4Q) looks at the process in great depth.

Follow-up
The issue of recycling batteries is taken up in the following activity.

Fact checking

All the batteries on earth can store only ten minutes of the world's energy needs.

– Isador Buchmann (2011)

Overview

The quotation cited above is provocative in several ways. For example, what is the world's energy needs? How many batteries are there on earth?

Certain questions are the epitome of intractability, in which the answers are often based on incomplete, even unattainable information and represent, at best, estimates that may be correct only within an order of magnitude. Enrico Fermi was famous for such "back-of-the-envelope" calculations, which are even sometimes referred to as Fermi problems. In his classic work, *Consider a Spherical Cow*[11], John Harte demonstrated numerous examples of solving environmental problems in order to "arrive at an approximate solution" (p. xiii).

Problem solving in high school chemistry classes is usually approached through *dimensional analysis*, in which units of measurement are converted from one unit to another. As an exercise, students will be provided with certain "facts" in order to check the veracity of Buchmann's assertion.

According to the International Energy Agency (2015), the total world energy consumption in 2013 was 13,541 Mtoe[12] (p. 6). A megatoe (Mtoe) is 10^6 tonne of oil equivalent (toe), a unit of energy defined as the amount of energy released by burning 1,000 kilograms of crude oil. The IEA provides a unit converter online at http://www.iea.org/statistics/resources/unitconverter for other energy equivalents. For instance, 13,541 Mtoe equates to 5.6694×10^{20} joules, the total world energy consumption.

Efforts to determine how many batteries there are in the world are much more tenuous. The Freedonia Group, an international market research group, estimates the world production of batteries to be around $86.2 billion (http://www.freedoniagroup.com/ industry-study/2703/world-batteries.htm), but this number does not easily lend itself for use in a solution. Nor would figures that estimate the number of batteries thrown away each year in the United States (around 3 billion[13]) be especially helpful.

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[11] Harte explains the origin of the book's title in the Preface (p. xiii). Later, he asks the reader to "provide [an] order-of-magnitude answer" to the question, "How many pairs of shoes can be made from a cow?" He offers a hint, "consider a spherical cow – and a spherical shoe, to boot" (p. 4).

[12] According to the graph provided, this amount was approximately 12,500 Mtoe in 2011.

[13] http://everyday-green.com/html/battery_statistics.html

A more satisfying approach might be to have students estimate the number of 9V batteries that would be required to provide 10 minutes of the world's energy needs:
10 minutes of the world's energy needs could be converted as follows:

$$5.6693 \times 10^{20} \frac{\text{joules}}{\text{year}} \times \frac{1 \text{ year}}{365 \text{ days}} \times \frac{1 \text{ day}}{24 \text{ hour}} \times \frac{1 \text{ hour}}{60 \text{ minutes}} \times 10 \text{ minutes} = 1.0786 \times 10^{16} \text{ joules}$$

A "conservative" estimate of the power capacity of a 9V alkaline battery (http://www.techlib.com/reference/batteries.html) is 500 mAh. Since power (in watt-hours) is current x volts, and 1 watt-hour is 3600 joules, a single 9V battery would contain 16,200 joules of energy:

$$500 \text{ mAh} \times \frac{1 \text{ Ah}}{1000 \text{ mAh}} \times 9 \text{ V} = 4.5 \text{ Wh}$$

$$4.5 \text{ Wh} \times \frac{3600 \text{ joules}}{1 \text{ Wh}} = 16,200 \text{ joules}$$

Dividing the world's energy needs calculated above by the power capacity of a 9V battery indicates that 666 billion 9V batteries would be needed to supply the world's energy needs. Using D batteries (13,000 mAh, 1.5V) would require about 1/4 as many batteries.

Materials

- paper
- calculator
- energy unit conversion table (see below)
- computer with Internet access (optional)

Procedure

1. This exercise can be used as a warm-up exercise. Students will have had some practice with using dimensional analysis to perform simple conversions (*e.g.*, how many seconds are there in a year?).
2. The teacher may present a typical Fermi-type problem (*e.g.*, how many gallons of water are there in all of the oceans of the world?) and ask the students what they would need to know in order to solve such a problem.
3. The teacher cites the Buchmann statement and asks students to comment on whether the assertion seems reasonable.
4. Students will use dimensional analysis to estimate the world's energy needs for 10 minutes.
5. Working in groups, students will calculate how many batteries of a particular type would be needed to provide this amount of energy.

6. Students will compare their results in order to evaluate the original claim.

Discussion
Topics brought up in this activity can lead in many directions. Students might be encouraged to question the assumptions made in order to perform the calculations (*e.g.*, how accurate is the estimate of the energy needs of the entire world?). Or students might consider how this estimate correlates to energy usage per person on the planet; students could then attempt to estimate their own energy usage.

Follow-up
Have students consider the following statement:

According to the Environmental Protection Agency (EPA), each year Americans throw away more than three billion batteries. That's about 180,000 tons of batteries. More than 86,000 tons of these are single use alkaline batteries. Imagine, placed end to end these dead alkaline batteries alone would circle the world at least six times. About 14,000 tons of rechargeable batteries are thrown away in the United States.

– http://everyday-green.com/html/battery_statistics.html

Students will be asked what "facts" they would need to verify the assertions made. For instance: What is the circumference of Earth? How long is an alkaline battery? Additionally, students can consider the number of batteries thrown away, on average, by every person in the U.S. (about 10).

General conversion factors for energy

To:	TJ	Gcal	Mtoe	MBtu	GWh
From:	multiply by:				
TJ	1	2.388×10^{2}	2.388×10^{-5}	9.478×10^{2}	2.778×10^{-1}
Gcal	4.187×10^{-3}	1	1.000×10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.187×10^{4}	1.000×10^{7}	1	3.968×10^{7}	1.163×10^{4}
MBtu	1.055×10^{-3}	2.520×10^{-1}	2.520×10^{-8}	1	2.931×10^{-4}
GWh	3.600	8.598×10^{2}	8.598×10^{-5}	3.412×10^{3}	1

– IEA (2015), p. 58

Infographic

Overview
An infographic is a visual representation of information. It can illustrate a simple fact or condense vast amounts of knowledge into a form that is readily discernible. In other words, an infographic is "data sorted, arranged, and presented visually."[14]
In this activity, students will examine several infographics critically and then create their own infographic using an online tool such as found at Infogr.am, Venngage.com, or Piktochart.com.

Materials
- projector
- computers with Internet access

Procedure
1. Students will examine several infographics and interpret the information presented.
2. The teacher will lead a discussion on what makes a good infographic.
3. Students will draw a sketch of an infographic to illustrate the fact(s) they researched previously.
4. Students will select a web tool to use to create their project, being sure to cite their sources.

Discussion
A selection of samples as well as a presentation on infographics can be found at http://www.cabarrus.k12.nc.us/Page/23236. Additional information on creating infographics can be found at http://mashable.com/2012/07/09/how-to-create-an-infographic/#9uYAeDpjs5qL, http://www.schrockguide.net/infographics-as-an-assessment.html.

Follow-up
The infographics that students create may be used on the culminating activity,
A plan of action for sustainability.

[14] http://www.hotbutterstudio.com/#/alps/

A plan of action for sustainability

Overview
The Environmental Protection Agency defines sustainability as "the ability to maintain or improve standards of living without damaging or depleting natural resources for present and future generations."[15]

This activity will focus of the development of a plan to address the issue of battery disposal for stakeholders in public schools. This activity can also be integrated within the larger scope of sustainability as it relates to the school's recycling efforts. According to a survey conducted by Ipsos Public Affairs, "Nine in ten adults (87%) report that they recycle, though only half of adults (51%) recycle every day."[16] The School District of Philadelphia recently announced the launch of "GreenFutures," the District's first ever Sustainability Plan.[17] District-wide recycling will be implemented during the next school year but will only entail collecting the more commonly recycled materials (https://www.youtube.com/watch?v=XAjXosyHNGM) in the standard blue bins. There are no plans at this time to deal with non-standard (but recyclable) materials such as batteries, although the Office of Information Technology's Educational Technology Group does have a program to handle other technology waste disposal.[18]

Materials
- projector
- computers with Internet access
- easel pads and markers (optional)

Procedure
1. Students will be polled on the extent to which they recycle at home. For example, they will be asked: What materials do they recycle? What percentage of the items they throw out is recyclable? Why do they recycle? What do they not recycle all the time?
2. The teacher will lead a discussion on the benefits of and barriers to recycling.
3. Students will be asked what impact there might be if consumers had to pay to recycle.
4. Working in groups, students will be assigned one of five types of batteries: household batteries (alkaline and zinc/carbon), button batteries, car batteries, rechargeable batteries, and large industrial batteries. They will determine the number

[15] http://cfpub.epa.gov/roe/chapter/sustain/index.cfm
[16] http://www.ipsos-na.com/news-polls/pressrelease.aspx?id=5285
[17] http://webgui.phila.k12.pa.us/offices/e/environmental
[18] http://webgui.phila.k12.pa.us/offices/e/environmental/programs--services/hazardous-material

of batteries used within their school, their homes, and local community and identify options and costs for handling disposal. Each group will present their findings and recommendations to the class.

5. A plan for action and a report will be compiled for the school district's Office of Environmental Services.

Discussion

A number of retailers, such as Lowes, Home Depot, Staples, and Best Buy, participate in the Rechargeable Battery Recycling Corporation's (RBRC) recycling program. Drop-off sites can be located at www.call2recycle.org/locator/, however these retailers generally do not accept single-use batteries.

Several companies offer fee-based services for shipping used batteries and electronics. These include Battery Solutions (www.batterysolutions.com) and the Big Green Box (biggreenbox.com). Prices are based on weight, and costs typically run $100 or more for up to 50 pounds.

The Philadelphia Streets Department (www.philadelphiastreets.com), which is responsible for the collection and disposal of residential trash and recyclables (as well as the construction, cleanliness and maintenance of the city's streets), accepts household batteries at its Household Hazardous Waste events held at least once a year at various locations (http://www.philadelphiastreets.com/events/household-hazardous-waste-events). Eforce Compliance (www.eforcerecycling.com), a commercial recycler in Philadelphia, also holds collection events for electronic waste, including batteries.

Annotated Bibliography/Resources

Print and Web:

Battery University < http://batteryuniversity.com>

Battery University™ is a free educational website that offers hands-on battery information to engineers, educators, media, students and battery users alike. The tutorials evaluate the advantages and limitations of battery chemistries, advise on best battery choice and suggest ways to extend battery life.

Buchmann, Isidor. (2011). *Batteries in a Portable World: A Handbook on Rechargeable Batteries for Non-Engineers*, 3rd Ed.
Richmond, BC: Cadex Electronics, Inc.

For the busy professional who needs a crash course on batteries; the engineer who searches for a battery to kick-start a product; the student who seeks answers for an academic project; as well as the everyday battery user who wants to learn how to extend the life of a battery.

Electronics TakeBack Colation. (2016, January 13). *Facts and Figures on E-Waste and Recycling*. <http://www.electronicstakeback.com/wp-content/uploads/Facts_and_Figures_on_EWaste_and_Recycling1.pdf>.

A summary of available statistics that help is to quantify the problems of electronic waste and e-waste recycling efforts

Everyday-Green. (2010). *Battery Statistics*.
<http://everyday-green.com/html/batteries.html>

Batteries. So easy to throw out! Why you shouldn't

Greenpeace. (2009, February 24). *Where does e-waste end up?*
< http://www.greenpeace.org/international/en/campaigns/detox/electronics/ the-e-waste-problem/where-does-e-waste-end-up/>.

The US Environmental Protection Agency (EPA) estimates that as much as three quarters of the computers sold in the US are stockpiled in garages and closets. When thrown away, they end up in landfills or incinerators or, more recently, are exported to Asia.

International Energy Agency. (2015). *2015 Key World Energy Statistics*. <http://www.iea.org/publications/freepublications/publication/KeyWorld_Statistics_2015.pdf >

The IEA publishes an annual compilation of its most used statistics, the Key World Energy Statistics, which contains "timely, clearly presented data on the supply, transformation and consumption of all major energy sources for the main regions of the world".

Rathje, W. and Murphy, C. (1992). *Rubbish: The Archeology of Garbage.* New York: HarperCollins.

Show what the study of garbage tells us about a population's demographics and buying habits.

Rechargeable Battery Recycling Corporation. *Charge Up to Recycle!® Battery Lesson Plan*. < http://www.panasonic.com/environmental/rbrc_lesson_plan.pdf>.

A series of activities that demonstrate how batteries work, explore different types of batteries, explain the need to recycle, and provide helpful battery usage and handling tips.

Teach Engineering. (2010). Hands-on Activity: Design, Build and Test Your Own Landfill. <https://www.teachengineering.org/view_activity.php?url= collection /cub_/activities/cub_enveng/cub_enveng_lesson05_activity2.xml>.

Students design and build model landfills using materials similar to those used by engineers for full-scale landfills.

United States Environmental Protection Agency. (2015, June). *Advancing Sustainable Materials Management: 2013 Fact Sheet.* <http://www.epa.gov/sites/production /files/2015-09/documents/ 2013_advncng_smm_fs.pdf>.

U.S. Environmental Protection Agency (EPA) has collected and reported data on the generation and disposal of waste in the United States for more than 30 years. These facts and figures are current through calendar year 2013.

Wiggins, G., and McTighe, J. (2005). *Understanding by design*, 2nd ed. Alexandria, VA: Association for Supervision & Curriculum Development.

A good introduction to the concepts of curriculum by unit development and problem-based learning, this book includes a useful template.

Appendix/Standards

PA Common Core Standards for Reading in Science and Technical Subjects, 11-12

CC.3.5.11-12.A
- Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

CC.3.5.11-12.B
- Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

CC.3.5.11-12.C
- Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

CC.3.5.11-12.D
- Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context.

CC.3.5.11-12.E
- Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.

CC.3.5.11-12.F
- Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.

CC.3.5.11-12.G
- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

CC.3.5.11-12.H
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

C.3.5.11-12.I
- Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

CC.3.5.11-12.J
- By the end of grade 12, read and comprehend science/technical texts in the grades 11–12 text complexity band independently and proficiently.

PA Common Core Standards for Writing in Science and Technical Subjects, 11-12

CC.3.6.11-12.A

- Write arguments focused on discipline-specific content.

CC.3.6.11-12.B

- Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

CC.3.6.11-12.C

- Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

CC.3.6.11-12.D

- Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

CC.3.6.11-12.E

- Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.

CC.3.6.11-12.F

- Conduct short as well as more sustained research projects to answer a question (including a self- generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

CC.3.6.11-12.G

- Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

C.3.6.11-12.H

- Draw evidence from informational texts to support analysis, reflection, and research.

CC.3.6.11-12.I

- Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

PA Academic Standards for Science and Technology

3.2.C.A4

- Predict how combinations of substances can result in physical and/or chemical changes.
- Interpret and apply the laws of conservation of mass, constant composition (definite proportions), and multiple proportions.

3.4.12.C3

- Apply the concept that many technological problems require a multi-disciplinary approach.

3.4.12.E3.

- Compare and contrast energy and power systems as they relate to pollution, renewable and non-renewable resources, and conservation.

PA Academic Standards for Environment and Ecology

4.5.12.A.

- Research how technology influences the sustainable use of natural resources.

4.5.12.C.

- Analyze the costs and benefits of means to control pollution.

4.3.12.D.

- Evaluate waste management practices.

4.5.12.E.

- Analyze how consumer demands promote the production of pollutants that affect human health.

Next Generation Science Standards

HS-PS1-7

- Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

HS-ESS3-1.

- Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

HS-ESS3-2.

- Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

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