Curriculum Units by Fellows of the National Initiative
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I Got the Power! Misconceptions of Recycling Batteries

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Introduction

The U.S. toy industry is worth over $22 billion dollars a year. The average person uses 32 batteries a year, so where do they go when they die? [1] American families purchase over 5 billion batteries, which is around 150,000 tons of battery waste annually. The average child receives 69 electronic toys a year, most being electronic toys. [2] How do you begin to make the students understand the impact they have in tossing their dead and broken electronic toys or devices? Items like cellular phones, batteries, televisions, broken computers, and even video game systems should not be tossed in the trash because they still contain dangerous chemicals and heavy metals that can end up in the landfill. Children are disconnected from the world outside their doors.

In 2010, our state science test indicatedthe students are struggling with retention of the science concepts, with an 8 th grade proficiency of only 28%, and 39% proficiency in 11 th grade. My students seem to struggle with comprehending some abstract science concepts and recognizing there is a relationship between evidence and explanation. Similarly, they don't seem to understand that background knowledge and accepted theories help them determine the design of the current experiments and interpretation of the data. The area in which they are most lacking is physical science. How do you build a foundation of what physical science is and how it can be applied to their world? My students reside in a city and are geographically limited to unspoiled areas of nature. They lack the experiences of wooded untouched areas. Thus, they have very little experience with the effects or impact that pollution has on the ground water or the soil. They do not seem to grasp that recycling is more than separating plastic, paper, aluminum, and glass.

The science literacy of our students may well determine the path they choose to follow in the future. Thus, by allowing my students to participate in science-based decisions, we can hope to diminish the harmful impact of pollution of our air and water in our community.

The Tire Fire of 1997 in Washington, Pennsylvania, evacuated our students during the school day when burning pieces of flaming tire residue rained down from the sky as the middle school students during were getting on the buses at the end of their day. Our school and the several hundred families were evacuated for three months and could not return per orders from the EPA due to hazardous air quality, soil contamination, and water compromised. Governor Tom Ridge declared a Proclamation of Extreme Emergency. [3]

My first-hand witness of this environmental disaster made me realize how much of an impact hazardous waste can affect a whole community. My unit is a reflection of how improper recycling, such as the used tires, can affect a whole community.

Rationale

I teach in a small inner city school district that has a demographic population of 1619 students which includes 878 in grades K-6 grade with 52% being low-income, 236 in middle school grades 7-8 with 14% being low-income, and 505 students in high school with 33% of low-income. Economically, 64% of our population qualifies for free or reduced lunch status, 19% of the total population requires special education services, and 3% are eligible for gifted services.

I plan to bridge the gap of what chemistry is by teaching what a battery is, what a battery is made of, what are its applications, and how to recycle a battery responsibly. With society so environmentally aware of potential hazards of materials that need to be recycled, it is imperative that I educate my students of about chemicals in batteries, why they are hazardous and why it is so dangerous to put them in our garbage cans to be hauled away to the local landfill.

As my knowledge of the components in a battery increases, it has have made me realize that simply tossing them in our local landfill will have a negative impact on our environment. I came to the realization that it is my role as a science teacher to educate my students and make them aware with facts, background, experiments, and investigations to adequately show them the misconceptions of recycling. I intend to emphasize recycling of not just paper, plastic, aluminum, and glass but of the batteries that we can't seem to live without to power our everyday devices. I hope to empower my students' interest in recycling in their homes, school, and neighborhoods and to have a positive influence to teach others in the process.

The lessons and activities have been designed to show them the simple concepts of electrochemistry of a lemon battery, the types of batteries and the pH test for the materials that leach from batteries. Thus, I intend to make my students environmentally conscious of what they throw away. The lessons will then show my students the impact that they can have and make them more environmentally aware. The students will have a true understanding of what recycling is. My students will be taught the background information to guide them in science investigations and inquiry experiments, which then will allow them to discover for themselves.

Objective

In this unit, students will explore the application of electrochemical energy. By using investigation, minds-on strategies, and inquiry based activities, the student will become more ecologically aware of what impact batteries have on the environment, what their applications are, and will to be able to fully understand why responsible disposal is essential.

This unit will teach the students the basics of what a battery is and the chemistry behind it. Students will be exposed to the Periodic Table of Elements for the first time. I feel that by teaching them how to apply the concepts and principles of what a battery is and how it works, they can reach further, discover, and make cognitive connections with other concepts in physical science. Through the recycling of batteries and understanding of some of the misconceptions of how improper disposal of batteries,I believe we can have a significant impact on our local environment.

Being the only science teacher in 6 th grade, I have noticed specific areas of interest and curiosity amongst my students especially with the technological devices they use daily. They are constantly complaining about the batteries that power them. The students are frequently asking me why the batteries die.

This Curriculum Unit is designed for grades 5 through 7. It has been organized to be taught with our plant unit in the sixth week of school when the students learn science laboratory safety. This unit will be taught over a three week period. Concepts and activities, experiments, and investigations will be taught in a sequence that will build upon prior work to ensure understanding and subsequently enrich the experience.

Our science book is an integrated spiral approach which uses consecutive concepts in earth, space, physical, life, and environmental sciences to teach concepts from one grade level to build upon the next grade level. Without a firm background and understanding of the chemical concepts, the students will lack the skills to infer for themselves and to allow them to be successful. My goal is to have my students experience with hands-on, minds-on investigations and activities.

Background

There exist many misconceptions regarding the nature of materials that can be successfully recycled. Questions arise as to the efficiency and success of recycling programs. [4] More than 3 billon alkaline and rechargeable batteries are purchased every year in the U.S. and end up in a dump. [5] Our developed world is running out of suitable municipal landfill locations, and even the most reliable sites are responsible for releasing methane into the air and leaching harmful toxic pollutants in the water and soil. Poorly lined landfills can also exude leachate and leak hazardous metals into the local groundwater. Landfills are often lined with clay or plastic and then sealed without oxygen. When waste breaks down slowly over a long period of time, methane is released and produces a greenhouse gas 21 times more potent than CO_2. Waste is only waste if nothing can be done to make it useful. It can also be a resource. Recycling is reprocessing of recovered materials at the end of a product life, returning them once again into the use stream.

Attitudes toward Recycling

Recycling is the simplest single most responsible thing a citizen can do individually to help solve the problems of waste management. Our personal behaviors deem that our daily habits directly contribute to whether we practice sound management and set an example for those who are less informed and educated but really want to do the right thing. We as ordinary citizens paired with business and industry have an impact on our community. Simply by starting with household waste such as the batteries, which our students are most familiar, they can have an impact on their own community. The main reason for recycling batteries is to prevent hazardous materials such as cadmium, mercury, lead, and zinc, from entering the landfills. Recycling is a simple way to help reduce unnecessary waste in our environment.

Legislation and Responsibility

President Obama was quoted as saying "If we want to reduce our dependence on oil, put Americans to work, and reassert our manufacturing sector as one of the greatest in the world, we must produce the advanced, efficient vehicles of the future." He announced more than $2.4 billion dollars in grants to accelerate manufacturing and deployment of the next generation of U.S. batteries and electric vehicles. [6] The funding was under the American Recovery and Reinvestment Act. More than 48 new and advanced battery and electric drive projects were selected through the Department of Energy, which will accelerate the development of U.S. manufacturing capacity for batteries and electric drive components as well as the deployment of electric drive vehicles. 5 billion dollars were allocated for manufacturing of batteries and to expand battery recycling capacity. [7] We are fortunate that mercury, used to prevent corrosion and to ensure long shelf life, was largely phased out of batteries with the Mercury-Containing and Rechargeable Battery Management Act of 1996. Efficient and cost-effective disposal of used nickel cadmium (Ni-Cad) batteries used small sealed lead-acid (SSLA) batteries, and other regulated batteries. [8]

Today's common household single use batteries AA, AAA, C, D, and 9-volt, don't pose as a great of a threat to modern landfills as they used to because they contain much less mercury than their predecessors. The trend is that some municipalities will accept these batteries at hazardous-waste facilities, which will send them to be processed. Recycled components create new batteries. Recycling centers receive 0.85 cents per pound. [9] Spent rechargeable batteries from lap top computers, cell phones, and MP3 players pose a big issue. Although the rechargeable batteries that power them have many environmental advantages, they typically have toxic heavy metals that make them a threat to both landfills and incinerators if not recycled properly.

Effects of Hazardous Waste

The effect of environmental contaminants on health is a major concern because exposure is associated with an increasing number of diseases including diabetes, cancer and even infertility. [10] Currently, the U.S. Environmental Protection Agency regulates at least ten metals, including Pb, Cd, and Cu, and unregulated metals like Ni and Zn will be monitored in the future. These elements are found in e-waste and other sources, as primary contaminants in drinking water. [11] Lead is an environmental contaminant found in municipal waste that can damage every human organ system. [12]

History of a Battery

Dating back some four and a half thousand years ago, we are sure that recovered ancient copper vessels were discovered plated with gold by an electrochemical process. This battery was found near Bagdad and was known as the Parthian. [13] It wasn't until 1800 that Alessandro Volta invented the volta cell. Volta discovered that certain fluids would generate a continuous flow of electrical power when used as a conductor. The volta battery was made by stacking alternating layers of zinc, blotting paper, soaked in salt water, and silver. This battery was known as the voltaic pile. Englishman, John F. Daniell invented the Daniell Cell in 1836, which used two electrolytes: copper sulfate and zinc sulfate. The Daniell cell lasted longer than the Volta cell. In 1859, the first rechargeable battery was invented by Gaston Plante which was based on a lead-acid cell, a system still used today. [14]

The first inventor credited with the useable primary battery was George Leclanche whose invention in 1860 used a mixture of manganese dioxide and coal as a positive electrolyte and used amalgamated zinc as a negative electrode with a current collector of coal and a solution of ammonium chloride. [15]

History of Chemistry

Dating back to more than 10,000 B.C., objects of such as jewelry and tools were carved or cut from gold, silver, and copper. In 3,200 B.C., copper was mined on a large scale in Egypt. Copper was used in the making of bronze during the Bronze Age. In 1,550 B.C., plows of bronze were used in what is now Vermont. In 400-300 B.C., the term element is coined by Plato, the famous Greek philosopher. The Greeks consider the four basic kinds of matter, or elements, to be fire, water, earth, and air. In 700-1,300 A.D., Chemistry develops into an experimental science through the efforts of the alchemists. They learn many things about how elements behave and combine with each other. In 1,661, Robert Boyle, an English chemist, re-introduces the idea of basic types of matter called elements. Another English chemist, John Dalton in 1803, proposes his atomic theory. Dmitri Mendeleev, a Russian scientist, develops a periodic table of elements. [16]

What is a Battery?

Electrochemical power sources or batteries are devices that convert energy stored in chemicals into electrical energy. A battery produces an electric current when its terminals are connected to another to form a circuit. All batteries contain two electrodes and an electrolyte which produce the chemical reaction with the electrolyte carrying a current. In dry batteries, the electrolyte is a paste consisting of powdered chemicals. Wet batteries, which are used in cars, contain a liquid electrolyte. A battery's voltage depends on the metals used in its electrodes. According to the EPA, a battery means a device consisting of one or more electrically connected electrochemical cells that are designed to receive, store, and deliver electric energy. [17]

A cell of a battery has two electrodes and an electrolyte. Between the electrodes are positive and negative ions. Positive charged ions have fewer electrons than protons, and in negatively charged ions, there are more electrons than protons.

The electrons react with the electrolyte. Electrons leave one of the electrodes and build up on the other. Work is done in separating the charges, and that work is stored in the battery as electrical potential energy.

How do Batteries Work?

A battery is made up of many cells. A liquid called an electrolyte is in each cell. This liquid is made up of countless of billions of positive and negative charges. Two rods made of different materials are submerged in the electrolyte in each cell. The rods are called electrodes. A chemical reaction in the electrolyte sends positive particles to one electrode and negative particles to the other. When a wire is connected to the two electrodes, current flows along the wire. This current can be used to power a device. When the chemicals in the cell have been used up, the current no longer flows. [18]

Electric Current

Atoms have a positively charged nucleus surrounded by several negatively charged particles. The electrons carry the same amount of negative charge. So the charge on the nucleus is equal in size to the total charge of all the electrons in an atom. Sometimes an element can have a net positive or negative charge by gaining or losing electrons in which we call ions. [19]

Ohm's Law

Ohm's Law defines the relationship between power and voltage, current and resistance. One ohm is the resistance value through which one volt will maintain a current of one ampere. Current is what flows on a wire or conductor like water flowing in a stream. Current flows from negative to positive on the surface of a conductor. Current is thus measured in A amperes or amps. Voltage is the difference in electrical potential between two points in a circuit. It's the push behind current flow through a circuit, which is measured in V volts. Resistance determines how much current will flow through a component. Resistors are used to control voltage and current levels. A very low resistance allows a large amount of current to flow. A very high resistance allows a small amount of current to flow. Resistance is measured in ohms. Power is the amount of current times the voltage level at a given point measured in wattage or watts. ? is the symbol that represents ohm. [20]

Electrical potential energy can be calculated using the formula: V=IR

I=current (amperes) and R = resistance (ohms)

Uses for Recycled Batteries

Lead-acid batteries are now recycled through retailers for recycling. Lead-acid batteries have the highest recycling rate in that 99 % of the lead is recycled and a typical battery contains 60 to 80 percent recycled lead and plastic. [21] The recycling market is polypropylene castings, lead in used plates and other battery components. The battery acid is made neutral and made into sodium sulfate before being sold for laundry soap, textile manufacturing, and glass. The reason for the high rate of success is contributed to the ease of returning when purchasing a new battery and the increased value of lead and plastic components of the used battery itself.

Public Awareness and Education

The public has a lack of knowledge, lack of resources, and varying misconceptions about the kinds of batteries to recycle. We rely on communities and nonprofits to make consumers aware of what to do, why to do it, how to participate, and where to recycle batteries. Teachers can inform the youngest of consumers in their science classes through education.

Thenonprofit rechargeable battery and cell phone program, Call2Recyle, has partnered with tool giant DeWALT, Lowe's Home Improvement Stores, Staples, and RadioShack, to launch an awareness campaign to educate the consumers and businesses alike, about the ease and importance of diverting more than one million pounds of batteries from ever reaching landfills. According to Carl Smith the CEO for Call2Recyle, millions of batteries are not being recycled because people don't know they can be or where to take them for recycling. [22]

Public education and participation are keys to any recycling program. A public education program can heighten awareness and involve more individuals and businesses, and increase the number of batteries collected. Like all manufactured products, however, batteries have impacts on the environment at every stage of their life cycle. The metals used to manufacture batteries are non-renewable finite resources, and mining and processing of metal ores is also energy-intrusive. Batteries also have environmental impacts at the end of their life. While most automotive batteries are currently recycled, the majority of the smaller dry cell batteries are still going into landfills. The public needs to know the environmental impacts and how the recycling of batteries is linked to the materials they are made of.Cities with diverse ethnic groups face the greatest challenges in securing broad participation and, therefore, must typically spend more on recycling education.

Battery Types

Primary Batteries

Primary batteries are classified as single use batteries. Most household batteries are used for consumer goods such as telephones, flashlights, radios, watches, toys, and computers. There are five common primary-cell batteries: alkaline-manganese, carbon-zinc, zinc-air, mercuric-oxide, and silver-oxide. The most commonly used household battery is the alkaline-manganese (see figure 1 [25]).

Secondary Batteries

Secondary batteries are classified as rechargeable batteries and can be charged over and over again. The most common secondary-cell or rechargeable battery is the nickel-cadmium battery which is commonly found in rechargeable appliances. Common uses are rechargeable appliances, portable power tools, hand-held vacuums, camcorders, cellular phones, and lawn mower starters (see figure 2 [26]).

Applications of Rechargeable Batteries

According to Deoittle Consulting Company reports, it is estimated that there will be a 2-5% electric vehicle market share by 2020. One can argue that a strong increase in renewables could result in such cheap electricity the consumers would jump to buy electric vehicles. But energy renewable sources are not cheap, and even the government's projection of U.S. renewables as a percentage of totals of electric generation is just 14% by 2035. [24]

Rechargeable and Responsible Choices

One way to reduce the number of batteries in the waste stream is to purchase rechargeable batteries, period. Consumers need to actively participate in a rechargeable recycling program.

Strategies and Activities

This unit will primarily focus on recycling batteries, basic concepts of states of matter, electricity, and the electrochemistry of a battery. I will convey physical science concepts through hands-on, minds-on investigations with labs. The lessons will be broken down in five sections incorporating investigative labs after each concept presented. The initial lesson will be presented with a short video clip from a current event that was recently in the news. This will be projected via Smart board and a small discussion will follow. Finding out about my students' prior knowledge will better help me to provide them with the pertinent background knowledge to be successful. New concepts and vocabulary terms will be introduced and used as the unit unfolds.

Lesson One

This lesson starts with an introduction of recycling. The students will use their interactive notebooks and will work in groups of six to brainstorm what recycling means to them and ways they recycle at home, school, and in their community. Teams will also discuss potential hazards of not recycling. Pros and cons of recycling will be divided in the notebook. Teams will take turns and present their brainstorming ideas to the class using the Smart board. This pre-assessment of what knowledge the students have will determine how much time will be focused on the background information such as history, components, what a battery is, applications, and recycling. The students will discover that science is a way of using what we know to find out things we don't know. They will discover ways to solve problems scientifically.

Objectives:

*Students will explain the ways they recycle.

*The students will discuss the pros and cons of recycling.

*Identify the hazards associated with not recycling.

The teacher will present background information on the statistics of batteries that end up in landfills. The class will then estimate how many batteries they use a day. The class will calculate how many are used per week, month, and year. Hazardous materials will be discussed that are leached out of batteries into the ground. The students will discuss the products they know that are successfully recycled into something else.

Teamwork assignment:

The history of the battery will be presented in a timeline that will be copied and placed in the students' interactive notebooks. Students will work in teams to review the history of a battery. Other inventions and discoveries will be discussed associated with the time period. Benefits of a portable energy source will be presented. Teams will present sections of the timeline to the class.

Lesson Two

What is a battery? How does a battery work? Using the Smart-board, I will record student answers of what they know. I will then present the diagram of the cross section of a battery. The students will cut and paste a copy of a cross section of a battery in their interactive notebooks and label each component part. Essential questions will include: what did the first inventors use to make a battery? After a brief discussion, common metals will be presented and conductivity of such metals will be explained.

So how does charge flow from a battery through a light bulb? Every electrical circuit has some basic parts. Students will investigate, in the lemon battery investigation, some simple ways those parts go together to complete closed path called a circuit.

Students will learn through scientific problem solving by using an experiment, model, or observation to gather information to see whether their hypothesis is correct. Sometimes you need to alter your hypothesis, and sometimes you discover that the initial hypothesis is wrong. That's not failure. It's progress, because you now know you can make a new hypothesis and test it. In the lemon battery investigation, students will use observation to form a hypothesis.

Lesson Three

Investigation 1 Lemon Battery Lab

We will start by making a lemon battery to demonstrate electrochemistry, using zinc and copper nails, wire, and a bulb. The students will identify the electrodes of the closed system. Copper is the cathode and is positive. Zinc is the anode and is negative. The students will sketch what they will discover in their lab booklet which shows the path of Zn losing electrons and traveling to the other electrode. The H^+ ions from the electrolyte citric acid in the lemon has lots of hydrogen ions with a + charge. These H^+ ions take electrons that were deposited in the copper electrode: $2H^+ + 2e^- \Rightarrow H_2$. Electricity is produced because the loop is closed. By closing the loop, this allows the electrons to flow. An extension of the lab will be to have each lab group of six students chose another battery source from a variety of fruits and vegetables from the lad distribution area. I will facilitate the full inquiry technique. In full inquiry, students will be presented with a question. From this, they will design another investigation that they can conduct to answer the question. Students will have the opportunity to reach beyond what was demonstrated and work with their lab groups to discover by use of inquiry what will power their device. After each lab, the students will have the opportunity to gather their results, analyze them to draw conclusions, and present their findings to others. I will refer back to states of matter to assess what the students learned. Students will calculate if the lemon generates approximately 0.9 volts x 0.0003 amps = 0.00027 watts. The formula is volts x amps = watts.

Lesson Four

Why recycle batteries? What are the hazards? How can citizens recycle batteries? What can be done? Students will work in teams to research the effects of hazardous waste on humans and the environment. Each team will present their findings to the class and make the realization that batteries can cause harm to the environment if not recycled properly. The students will present ways they think can help in recycling of common household batteries, rechargeable batteries, and lead-acid batteries in their community.

Investigation 2 Solid or Dissolved Solution: Which will conduct Electricity?

The Periodic Table will be introduced and the students will focus on metal, non-metals, and noble gases. I will demonstrate that solids such as table salt (NaCl), Epson salt ($MgSO_4$), and baking soda ($NaHCO_3$) do not conduct electricity. The students will then assist in dissolving the salt, Epson salt, and baking soda in water (H_2O) to see if this "dissolved" solution conducts electricity. They will realize that solids prohibited the ions from flowing and the dissolved solution had free flowing ions, in an electrolytic solution. They will learn to write an equation such as:

$MgSO_4 + H_2O \rightarrow Mg^{2+}$ (aqueous) + SO_4^{2-} (aqueous).

Lesson Five

Investigation 3 Air Battery (alternate lab)

Students will be introduced to the Iron Science Teacher from the Exploratorium and view national fellow Lesia Whitehurst (Exploratium.edu) take on the challenge with her students on developing an aluminum air battery paper. I will pause the part before the students try to make the motor work. The students will then work in lab groups to develop their own battery with aquarium charcoal, saline saturated paper towel, aluminum foil, wire leads and a device of their choice from a supply of motors, light bulbs, clocks, or fans to power. The students will then make a saturated NaCl solution in a small bowl. Then they will rip off a piece of aluminum foil approximately 30 x 15 inches, place the saturated doubled over paper towel over the foil, next gently pour over approximately ¼ of aquarium charcoal over the paper towel. Place one end of a lead wire in the center of the charcoal and the other lead should be clipped at the end of the foil parallel to the first lead wire. Keep in mind that the internal lead should touch only the carbon inside. Remember to keep the carbon from touching the foil. Gently fold like a large burrito. The students will then attach both leads to the motor they wish to operate. The lab teams will record what is happening. Gently push down on the foil wrapped battery and record what is happening. The motor or device should work. Point out that the outside aluminum electrode is the low voltage electrode; therefore, it's the source of electrons. The reaction that powers the battery occurs between the aluminum foil and oxygen from the air. Explain that the activated charcoal has many gas pockets giving it a large surface area which provides the oxygen to the electrode; thus, the reaction with aluminum occurs in an aqueous solution. The maximum current delivered is determined both by the voltage produced by the battery and the internal resistance of the battery. The charcoal is the conductor; thus, the resistance decreases as the charcoal pieces are pressed together.

Lesson Six

What effect do battery metal toxins have on the ecosystem? What acid levels are leached in the soil and water? Students will be given questions and form a hypothesis to formulate an answer. The students will conduct a pH water lab investigation.

Investigation 4 pH Water Test

The students will watch me place an opened battery that I will open prior to lab, in a container of water and make predictions and form a hypothesis of how the battery will affect the pH. Each lab team will use a water testing kit containing phenol red. The students will use the clear container and read the color change indicating the pH level; the students will then compare the levels to a pH scale determining what pH levels are acceptable. We will discuss the acid, base, and neutral levels and the hazards of the bases from the batteries in landfills and the problems associated with it.

Investigation 5 Hazardous Waste Ecosystem

Lesson Seven

The final lab will be the culminating activity where students design an ecosystem with a small aquarium with plants, soil, worms, insects and a leach bed landfill system to simulate their community. Each lab team will have a control and an experimental ecosystem for this experiment. The variable will be the battery water. The battery contaminated water will be used to water their ecosystem. The students will observe and make record their results. The students will make a final poster board or Smartboard presentation to the class on their results. Students can record the pounds of batteries collected and calculate the benefits of reducing the landfills.

Extension Activity

Students can spearhead a recycling program in their neighborhoods. They can coordinate the education of it by holding small town talks and invite a member from the EPA or other environmental agency to speak. The students can make posters, flyers, and coordinated collection of containers or large re-sealable bags with instructions of where to take the filled containers for recycling.

Primary Batteries (figure 1) [25]

Type	Name	Sizes	Contents	Uses	Disposal class	Disposal
Alkaline Manganese	Alkaline	AA, AAA, C, D 6V, 9V	Manganese Oxide, Zinc, alkaline solution	Toys, calculators, smoke alarms, remotes, flashlights	Federal Non-hazardous	Normal municipal waste
Button Zinc-air	Mercury oxide Silver oxide Lithium Alkaline Zinc-air	vary	Silver Oxide, zinc, alkaline solution	Watches, hearing aids, toys, greeting cards, remotes	Hazardous waste	Household hazardous waste collection site
Nickel-Cadmium	Ni-Cad	AA, AAA,C, D, 6V, 9V	Nickel-oxide, Cadmium, alkaline solution	Cellular phones, power tools, computer packs, flashlights	Hazardous waste	Recycling center household waste collection site
Carbon-Zinc	Heavy duty	AAA, A, C, D, 6V, 9V	Manganese oxide, zinc, ammonium and/or chloride; zinc chloride	Transistor radios, calculators, toys, flashlights, calculators, smoke detectors, remotes, garage door openers	Non-hazardous waste	Normal municipal waste

Secondary Batteries (figure 2) [26]

Type	Common Name	Sizes	Contents	Uses	Disposal Classification	Disposal
Lithium Lithium-ion	"lithium" on label	3V, 6V, 3V button	Lithium Organic salt solution Various metal oxides	Cameras, calculators, computer memory back up	Non-hazardous waste	Can be recycled. Take to recycling center.
Nickel-Cadmium	Ni-Cad	AA, AAA, C, D, 6V, 9V	Nickel-oxide Cadmium, alkaline Alkaline solution	Toys, cellular phones, power tools, cameras, power packs	Hazardous waste	Hazardous waste collection site
Ni-MH rechargeable	Ni-Li of Ni-Hydride	AAA, AA, C, D, 6V, 9V	Nickel Manganese	Cellular phones, flashlights, power tools, computer packs	Non-hazardous except CA	Rechargeable center, safe for disposal in normal municipal waste.
Lead-Acid	AutoZone, Sears	12V, 6V	Sulfuric acid, lead	Cars, trucks, motorcycles	Hazardous waste	Take back to place of purchase Recycling

Teacher Resources

Battery Science: Make Widgets That Work and Gadgets That Go [Spiralbound] Doug Stillinger

Bubbles to Batteries (Investigation in Science: A Modular Approach: Matter and En) [Paperback] C.R. Gore

Cobb, Cathy, and Monty L. Fetterolf. *The Joy of chemistry: the Amazing Science of Familiar Things*. Amherst, N.Y.: Prometheus Books, 2010.

The amazing science of familiar things.

Hands-On Chemistry Activities with Real-Life Applications: Easy to use Lab Demonstrations for grades 8-12 [Paperback] Norman Herr, James Cunningham

Illustrated Guide to Home Chemistry Experiments: All Lab, No Lecture (DIY Science) [Paperback] Robert Bruce Thompson

http://onlinelibrary.wiley.com/doi/10.1002/adma.201003587/abstract

Moss, Doug. *Earth Talk. ; Expert Answers to Everyday Questions about the Environment.*. New York, New York: Penguin Group, 2009.

Expert answers to everyday questions about the environment.

http://pbskids.org/zoom/activities/sci/lemonbattery.html (Lemon Battery Experiment)

Easy lemon battery experiment.

Yarrow, Joanna. "Power Down." In *How to reduce your carbon footprint: 365 simple ways to save energy, resources, and money*. San Francisco: Chronicle Books, 2008. 91.

How to Reduce your Carbon Blueprint is the world's citizen's guide to pushing back the advance of global warming.

Yarrow, Joanna, and Caleb Klaces. "Problems of Landfills." In *Eco logical!: join the debate!-all the facts and figures, pros and cons you need to make up your mind*. London: Duncan Baird Publishers, 2009. 32-33.

Student Resources

Gibbons, Gail. *Recycle!: A Handbook for Kids*. Boston: Little, Brown, 1992.

Ever wonder what happens to all that plastic, glass, paper, aluminum, and polystyrene after the trucks pick it up?

Hiaasen, Carl, and Jennifer Welvaert. *Hoot* . Moline, IL: Moline Public Library, 2007.

A boy who becomes involved in another boy's attempt to save a colony of burrowing owls from a proposed construction site.

Meredith, Susan, and Christyan Fox. *Why Should I Recycle?* . London: Usborne, 2010.

Confused about recycling? This book will make you an expert, and get you involved.

Roca, NuÃŒBria, and Rosa Maria Curto. *The three R's: Reuse, Reduce, Recycle*. Hauppauge: Barrons Educational Series, 2007.

The three R's teaches us many things we can do to reduce pollution.

Showers, Paul, and Randy Chewning. *Where does the Garbage go?* . Rev. ed. New York, NY: HarperCollins Publishers, 1994.

Follow a garbage truck to a landfill to see how trash keeps piling up.

Appendix A

1. Pennsylvania State Assessment
2. Subject Area - 3: Science and Technology and Engineering Education
3. Standard Area - 3.2: Physical Sciences: Chemistry and Physics
4. Organizing Category - 3.2.A: Chemistry
5. Grade Level - 3.2.6.A: GRADE 6
6. Standard
7. 3.2.6.A1:
8. Distinguish the differences in properties of solids, liquids, and gases.
9. Differentiate between volume and mass. Investigate that equal volumes of different substances usually have different

masses.

10. 3.2.6.A2: Compare and contrast pure substances with mixtures.
11. 3.2.6.A4: Differentiate between physical changes and chemical changes.
12. 3.2.6.A5:
13. CONSTANCY AND CHANGE
14. Identify characteristic properties of matter that can be used to separate one substance from the other.
15. 3.2.6.A6:
16. Understand how theories are developed.
17. Identify questions that can be answered through scientific investigations and evaluate the appropriateness of questions.
18. Design and conduct a scientific investigation and understand that current scientific knowledge guides scientific investigations.
19. Describe relationships using inference and prediction.
20. Use appropriate tools and technologies to gather, analyze, and interpret data and understand that it enhances accuracy and
21. allows scientists to analyze and quantify results of investigations.
22. Develop descriptions, explanations, and models using evidence and understand that these emphasize evidence, have logically
23. consistent arguments, and are based on scientific principles, models, and theories.
24. Analyze alternative explanations and understanding that science advances through legitimate skepticism.
25. Use mathematics in all aspects of scientific inquiry.
26. Understand that scientific investigations may result in new ideas for study, new methods, or procedures for an investigation or
27. new technologies to improve data collection.

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