What Did that Cell Phone Really Cost?

Alena Newpher-Lockard
Overbrook High School

Overview

This unit is a 10-lesson exploration into the life cycle of cell phones. The unit was designed for high school science students but may be easily adapted for middle school students. The unit will simulate a corporate leadership team and is focused on the topics of energy, sustainability and the environment. Students will look at the life cycle of the highest grossing phone of each of the top 5 Global mobile phone brands in 2014: Samsung, Apple, Lenovo & Motorola (merged), Huawei, and LG.

Rationale

My students seem to be unable to go anywhere or do much of anything without using or at least having their cell phones nearby. Cell phones have become a staple in our society. However, my students know little to nothing about their how their actual phones work, let alone about the resources that were put into them. According to the Morningside Recovery Rehabilitation Center, the average American spends 144 minutes a day using his or her phone during a 16-hour period. So what better way to grab my students' attention then to develop an entire unit centered on the distracting device?

According to GSMA Intelligence, "the definitive source of mobile operator data, analysis and forecasts", over 7.5 billion mobile connections are currently in operation as of 2015. Still it is estimated that half of the world population is without cell phones. As our world population increases it is only prudent to infer that the number of cell phones in use will also increase. However, based on the sustainability company e-Cycle, the average person upgrades their cell phone every 18 months, which amounts to 130 million devices being discarded each year in the U.S. alone. I want my students to understand that their choices are impacting their environment.

Background Information

Cell phones consist of nine basic parts, each of which has it's own life cycle:

- Circuit board/printed wiring board
- Liquid crystal display (LCD)
- Battery
- Antenna
- Keypad
- Microphone
- Speaker
- Plastic casing
- Accessories (adapters, headsets, carrying cases, decorative face plates, etc)

According to the United States Environmental Protection Agency, there are seven stages to a product's life cycle. These stages are: design, materials extraction, materials processing, manufacturing, packaging & transportation, useful life, and end-of-life. These stages are outlined below from the information obtained at http://www.epa.gov/osw/education/pdfs/life-cell.pdf.

1. Design

A product's design can influence each stage of its life cycle and in turn the environment. Design affects which materials will be used to manufacture a product. For example, cheaper materials are often less durable, which means the product will have a short useful life. The ideal is to design a phone with reuse, recycling and minimal disposal in mind. Products can be designed with modular components that can be easily replaced so that the entire product does not have to be thrown away if only one piece breaks. Items meant to last a long time can avoid trendy designs so they are not thrown away when they go out of style.

2. Materials Extraction

A cell phone is made up of many materials. In general, the handset consists of 40 percent metals, 40 percent plastics and, and 20 percent ceramics and trace materials. The circuit board (also called a printed wiring board) located in the handset, is the 'brain' of the cell phone because it controls all of its functions.

Circuit boards are made from mined, raw materials including copper, gold, lead, nickel, zinc, beryllium, tantalum, coltan, and other metals. The manufacturing of these boards requires crude oil for plastic, and sand and limestone for fiberglass. Many of

these materials are known as “persistent toxins” and can stay in the environment for long periods of time, even after disposal.

The liquid crystal display (LCD) is a low-power flat panel display on the front of your phone that shows information and images. It becomes opaque (hard to see through) when electric current passes through it. The contrast between the opaque and transparent (see-through) areas forms visible characters.

Various liquid crystalline substances, either naturally occurring (such as mercury, a potentially dangerous substance) or human-made, are used to make LCDs. LCDs also require the use of glass or plastic.

The rechargeable battery is used to power the phone. Cell phones can use several types of batteries: nickel-metal hydride (Ni-MH), lithium-ion (Li-Ion), nickel-cadmium (Ni-Cd), or lead acid. Ni-MH and Ni-Cd batteries contain nickel, cobalt, zinc, cadmium, and copper. Li-Ion batteries use lithium metallic oxide and carbon-based materials, all mined from the earth.

3. Materials Processing

Most raw materials must be processed before manufacturers can use them to make products. For example, in cell phones: Crude oil is combined with natural gas and chemicals in a processing plant to make plastic. Copper is mined, ground, heated, and treated with chemicals and electricity to isolate the pure metal used to make circuit boards and batteries. The resulting copper pieces are shipped to a manufacturer where they are formed into wires and sheets.

4. Manufacturing

Plastics and fiberglass are used to make the basic shape of the circuit board, which is then coated with gold plating. The board is also composed of several electronic components, connected with circuits and wires (primarily made of copper) that are soldered to the board and secured with protective glues and coatings. LCDs are manufactured by sandwiching liquid crystal between layers of glass or plastic. Batteries consist of two separate parts, called electronics, made from two different metals. A liquid substance, called electrolytes, touches each electrode. When an outside source of electricity such as an outlet is applied, chemical reactions between the electrodes and the electrolytes cause an electric current to flow, giving batteries their “juice” or power.

5. Packaging & Transportation

Cell phone parts and the finished products need packaging and transportation to get from one place to another. Transportation by plane, truck, or rail all require the use of fossil

fuels for energy, which can contribute to global climate change. While packaging protects products from damage, identifies contents, and provides information, excessive or decorative packaging can be wasteful. Packaging consumes valuable natural resources, such as paper (from trees), plastic (from crude oil in the earth), aluminum (from ore), or other materials, all of which use energy to produce and can result in waste. Some packaging; however, can be made from recycled materials.

6. Useful Life

Unlike other countries, cell phone companies in the United States sell their own phones, which are usually not interchangeable from company to company. Even though regulations now allow consumers to transfer their phone number to a new phone company, most companies have unique technologies in their phones that only work in their own networks.

This means that switching cell phone companies can mean having to purchase a new phone. One way to extend the useful life of your phone and prevent waste is to use the same company for continuing phone service. Always comparison-shop to be sure you get the service and phone that's right for you.

You can also extend the life of your phone by taking care of it—protecting it from damage by storing it in a case, avoiding dropping it, and keeping it out of extreme heat and cold and away from water and other liquids. The use of rechargeable batteries in cell phones reduces the amount of waste and toxicity that disposable batteries create. Be sure to follow the manufacturer's instructions for charging your batteries so you can extend their lives as long as possible.

7. End of Life

Donating or recycling cell phones when you no longer need or want them extends their useful lives, and prevents them from ending up in the trash where they can potentially cause environmental problems.

Many organizations—including recyclers, charities, and electronics manufacturers—accept working cell phones and offer them to schools, community organizations, and individuals in need. Reuse gives people, who could not otherwise afford them, free or reduced cost access to new phones and their accessories. Plus, it extends the useful lifetime of a phone.

Many cell phone manufacturers and service providers offer a "take-back" program. Under this system, manufacturers accept used cell phones and accessories and either recycle, re-manufacture, or dispose of them using systems designed to handle the specific

types of waste cell phones produce. Contact your manufacturer by using the information that came with your phone or via the Internet.

Electronics recyclers are springing up everywhere! Today, many stores, manufacturers, and recycling centers accept cell phones for recycling. While some electronics recyclers only accept large shipments, communities, schools, or groups can work together to collect used cell phones for shipment to electronics recyclers. Some rechargeable batteries can also be recycled, as several retail stores and some communities have started collecting them. When rechargeable batteries are recycled, the recovered materials can be used to make new batteries and stainless steel products.

Cell phones that are thrown in the trash end up in landfills (buried in the ground) or incinerators (burned). Because cell phones contain metals, plastics, chemicals, and other potentially hazardous substances, you should always recycle, donate, or trade in your old cell phone. It's free and easy. Don't throw it away! Phones that are thrown away waste energy and result in the loss of valuable resources.

A major cell phone manufacturer recently developed a way to recharge cell phone batteries using "muscle power." This hand-powered device provides 20 minutes of talk time after just three minutes of squeezing a hand-held generator! Other new technologies, such as hydrogen fuel cells and zinc-air and solar-powered batteries, are continuing their development and might ultimately replace current battery technology. These new alternatives will conserve natural resources and reduce waste.

Objectives

This unit seeks to engage students in a range of critical thinking skills. Students will plan and conduct a collaborative investigation in order to produce data that will serve as the basis for evidence. Students will undergo a simulation study of the life cycle of an already designed cell phone. Students will evaluate multiple steps of the life cycle in order to understand the impact these devices have on energy consumption and the environment. Students will decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data.

Strategies

Guided notes

Guided Notes are teacher prepared handouts that have blank spaces for writing down key concepts, facts, definitions, etc. They allow students the opportunity to demonstrate appropriate classroom behavior while promoting active engagement during a lecture. Guided Notes can increase on-task behavior, improve note-taking accuracy and help

improve academic performance. Guided Notes can easily be adapted to any instructional level and altered for students with specific skill deficits.

According to the handy Teacher Toolkit, there are 4 guidelines that allow for successful implementation of guided notes.

- Prioritize: Decide what is most important for students to understand in the presentation or reading for which they will be taking notes.
- Create: Prepare a set of notes that contains the essential information from the presentation or reading. Underline or highlight the key concepts, facts or information that students will be responsible for writing into the final version. Next, replace those concepts with blanks for the students to fill in.
- Explain: Prior to handing out copies of the Guided Notes in class, ensure that students understand their responsibility to fill in each of the blanks with the appropriate concepts, definitions, or other content to help them understand what they will be seeing, hearing, or reading.
- Review: Discuss the correct answers with the class as the presentation progresses or after the reading.

Cooperative Learning

Cooperative Learning is an instructional strategy in which groups of students work together on a common task. For this unit, groups of students will form cell phone brand corporations. Each group member is individually responsible for a specific part of the corporation. Researchers report that cooperation typically results in higher group and individual achievement, healthier relationships with peers, more metacognition, and greater psychological health and self-esteem (Johnson and Johnson 1989).

According to David Johnson and Roger Johnson (1999), there are five basic elements that allow successful small-group learning:

- Positive interdependence: Students feel responsible for their own and the group's effort.
- Face-to-face interaction: Students encourage and support one another; the environment encourages discussion and eye contact.
- Individual and group accountability: Each student is responsible for doing their part; the group is accountable for meeting its goal.
- Group behaviors: Group members gain direct instruction in the interpersonal, social, and collaborative skills needed to work with others occurs.
- Group processing: Group members analyze their own and the group's ability to work together.

FERMI Problems

A FERMI problem is a multi-step problem that can be solved in a variety of ways, and whose solution requires the estimation of key pieces of information. Mathforum.org states that FERMI Problems are posed with limited information given, require that students ask many more questions, demand communication, utilize estimation, and emphasize process rather than "the" answer. Students will be working as a team and sharing strategies and ideas, encouraging and supporting each other using social skills.

According to N. Pylypiw (2010), there are 5 central points to a FERMI problem:

- Focus on smaller problems
- Estimate when necessary
- Remember to round
- Make realistic assumptions and state them
- Include units

Classroom Activities

Lesson One: Introduction to Unit
Objectives: ● Students will be able to locate the major supply countries of manufactured goods. ● Students will be able to describe the 7 stages of a cell phone's life cycle. *Materials:* ● 7 sheets of chart paper (each one titled with a continent) ● Markers ● World map poster ● Prezi presentation on 7 stages of a cell phone's life cycle ● Guided notes for presentation *Do Now:* Have you ever considered where the products you use every day come from? Your job is to locate the "Made In" location for five items that are in your possession. *Instruction:* Seven pieces of chart paper, each titled with the name of a continent, will be hung up around the class. Students will be directed to use provided markers to write each country and item that they found from their Do Now on the corresponding continent chart paper.

Students that are unsure which continent the "Made In" country belongs to will be guided to look at the world map that is also hung up in the classroom. Students will then be asked to look for similarities and differences in the data collected. The teacher will model one observation and one inference from the data. An example of a model observation: no items were made in Antarctica. An example of a model inference: since it is so cold in Antarctica, companies cannot manufacture items there. Students will then be directed to make three observations and three corresponding inferences from the qualitative data found on the chart papers.

Now that the class has looked at where some of our products come from, the following question will be asked. Where do you think your products end up when you finish using them? After a brief period of wait time, pictures of piles of electronic trash throughout the world will be displayed using EcoWatch's website http://ecowatch.com/2015/04/14/bellini-electronic-waste/. Then a map from the United Nations Environmental Programme's Basel Action Network will be displayed that shows the "Known and Suspected Routes of e-waste Dumping." This map can be found at http://worldloop.org/e-waste/illegal-flows/.

Students will then be introduced to the concept that all products have a life cycle. Over the next few weeks of class, the class will explore the product life cycle of cell phones. Students will take down guided notes during a Prezi presentation that outlines the 7 stages of a cell phone's life cycle.

Homework:

Locate five different items at home and find out where they were made. Write a brief reflective paragraph about the journey of these items to your home.

Exit Ticket:

What are the seven stages of a cell phone's life cycle?

Lesson 2: Corporation Registry

Objectives:

- Students will join a cell phone brand corporation.
- Students will be hired for a specific position within their corporation.

Materials:

- Short clip - "How much does your iPhone really cost?" https://www.youtube.com/watch?v=IghsmsAAlvw
- Corporation registry handouts - (goo.gl/Z7XPpy)

- Position description handouts

Do Now:

The initial retail price for an iPhone 6 was $649. Write down an estimate for the actual cost of the hardware of the iPhone 6.

Instruction:

The short clip, "How much does your iPhone really cost?" provided by CNN Money will be used to spur discussion on the differences between cost of manufacturing and cost of production. We will review the seven stages of a cell phone's life cycle and discuss the costs associated at each stage to get a more accurate picture of what a cell phone really costs.
Students will look at the top grossing phone of each of the top 5 Global mobile phone brands in 2014: Samsung, Apple, Lenova & Motorola, Huawei, and LG. Students will select a brand to join (at most 6 students per brand). Then the students will review the position description handouts and elect positions for the mock phone brand corporations. Each corporation will consist of the following positions: CEO, Financial Controller, Logistics Coordinator, Product Manager, Executive Secretary, and Spokesperson. Each corporation is responsible for filling out the corporation registry handout. The corporation will also be directed to create self-government rules for four different categories.

Homework:

Review your position description handout.

Exit Ticket:

Rate you comfort level from 1-10 (1 being extremely uncomfortable to 10 being extremely comfortable) with the position you were hired.

Lesson 3: Design

Objectives:

- Students will replicate the design stage of the life cycle of a cell phone.
- Students will be able to describe the main features of a cell phone.

Materials:

- Computers (2 per corporation)
- Lesson activity sheets - (goo.gl/06Xbm6) & (goo.gl/f0Ym5H)

Do Now:

Which is better an iPhone 6 or a Samsung Galaxy 6? Give at least one reason why you chose the phone you did.

Instruction:

Teacher will review the design phase of the life cycle. Students will then simulate the design phase of cell phones by using an Edheads interactive located at www.edheads.org/activities/eng_cell/swf/index.htm. Each corporation will have two computers and will work in two groups. Activity 1: Designing a cell phone for senior citizens, follows the Edheads interactive exactly. Activity 2: Designing a cell phone for business people, only needs to use the design phase of the Edheads interactive. Once students are done, the two groups in each corporation will communicate their results.

Homework:

Design a cell phone for another subset of people and justify your design in at least one paragraph.

Exit Ticket:

What is the most important feature you look for in a cell phone?

Lesson 4: Materials Extraction

Objectives:

- Students will be able to name the 9 basic parts of their cell phone.
- Students will be able to identify and locate the main raw materials found in their specific cell phone brand.

Materials:

- Computers (2 per corporation)
- Used cell phone (one per corporation)
- 9 sticky notes per corporation
- Lesson activity on Google docs - (goo.gl/971bXJ)

Do Now:

Which elements do you think your cell phone is made up of?

Instruction:

Teacher will review the materials extraction stage of the life cycle. Teacher will then disperse the used cell phones already broken down into parts for each corporation. Corporations will have to identify the 9 basic parts by using sticky notes. Once each part has been identified, the corporations are to have the teacher check their identifications.

Then the corporations will research three main questions for each of the 9 basic parts. What materials are used? Why are these materials used? Where are these materials found? The corporations can decide how they would like to divide up the work.

Homework:

If your corporation did not finish today's assignment, finish it for homework.

Exit Ticket:

Name the 9 basic parts of your cell phone.

Lesson 5: Materials Processing

Objectives:

- Students will be able to explain how crude oil is processed to make plastic.
- Students will be able to explain how metal is processed to make wiring.

Materials:

- Computers (2 per corporation)
- Lesson activity sheet - (goo.gl/TxO9iA)

Do Now:

Here is an example: paper is made from trees, but the wood has to undergo several different processes before we can use it. Name another material that is processed before we use it?

Instruction:

Teacher will review the materials processing stage of the life cycle. Students will be taught that once raw materials are extracted from the earth they must be converted into a form that can actually be used. Corporations will use an interactive website (http://www.totalpetrochemicalsusa.com/flash/Wellheadtoplastics.swf) to explore how

crude oil is process to make plastic. Then the corporations will use another interactive website to explore how metal is processed to make wiring.

Homework:

Write down everything you use in the next 24 hours that contains plastic.

Exit Ticket:

What surprised you most about the processing of crude oil?

Lesson 6: Manufacturing

Objectives:

- Students will locate the main manufacturing locations for their cell phones.

Materials:

- Computers (one for each corporation)
- Lesson activity sheet - (goo.gl/73zjzC)
- World map sheets

Do Now:

Where do you think your corporation's cell phone was manufactured?

Instruction:

Teacher will review the manufacturing stage of the life cycle. Products are made in factories and require a great deal of energy to create. The manufacturing process can also produce pollution. A factory will be displayed showing cell phone manufacturing. Corporations are to research to find the main manufacturing locations for their cell phone brand. They will mark these locations on their world map sheets. FERMI problem: How much profit did your corporation make from the selling of your phone in 2014? Corporations will assume that all phones were sold at the initial US marketing price.

Homework:

Imagine you were working in one of the manufacturing plants in another country write an argumentative essay on why you should get a raise.

Exit Ticket:

What was your reaction when your corporation came up with its FERMI answer?

Lesson 7: Packaging & Transportation Day 1

Objectives:

- Students will be able to estimate the total mass of the packaging of the number of cell phones sold in 2014.
- Students will be able to estimate the CO_2 carbon emission pollution due to the transportation of the total number of cell phones sold in 2014.

Materials:

- Computers (one for each corporation)
- Packaging material for each phone
- Digital balance
- Lesson activity sheet - (goo.gl/u9QpW5)
- World map sheet

Do Now:

Think about something that you bought recently that came in packaging. What did you buy? Describe the packaging. Was it cardboard? Plastic? Did you have to unwrap multiple layers? Was a booklet included?

Instruction:

Teacher will review the packaging & transportation stage of the life cycle. Students will share their Do Nows with their corporation and the spokesperson will be asked to briefly share about the corporations' discussions. Then the teacher will pose two FERMI problems for each corporation to tackle.

The first FERMI problem will deal with packaging. What is your corporation's packaging mass for all cell phones sold in 2014? Each corporation will be given the typical packaging that their specific phone was sold in. Each corporation will be asked to list the parts of the packaging (plastic cover, barcode sticker, box, user manual, etc.). Then, each corporation will use a digital balance to weigh the packaging material. The corporation will have to research to find a valid approximation for the number of their cell phones that were sold in 2014. Each corporation will be asked to equate the mass of the packaging to some visual comparison. Example: 70 millions pounds of packaging material is roughly equivalent to 4,600 adult male African elephants.

The second FERMI problem will deal with transportation. What is your corporation's carbon footprint due to the transportation from your manufacturer location to the school

store for all cell phones sold in 2014? Disclaimer: the corporations will assume that all of the assembled cell phones in 2014 were shipped to the school store in order to be sold. Corporations will decide which modes of transit (plane, train, tractor-trailer) they will use to transport their cell phones. This problem will take an additional class period, as students will have to estimate numerous quantities.

Homework:

Write down a list of quantities that you would have to estimate in order to solve the transportation FERMI problem.

Exit Ticket:

Come up with one improvement to your brand's packaging that would lessen the mass of the packaging while maintaining its protection of the cell phone.

Lesson 8: Packaging & Transportation Day 2

Objective:

- Students will be able to estimate the CO_2 carbon emission pollution due to the transportation of the total number of cell phones sold in 2014.

Materials:

- Computers (one for each corporation)
- Lesson activity sheet - (goo.gl/DsRMjz)
- Packaging material for each phone
- Rulers
- World map sheet

Do Now:

Take out your homework and compile one list of quantities that your corporation would have to estimate in order to solve the transportation FERMI problem.

Instruction:

Teacher will facilitate a discussion on the quantities that have to be estimated in order to solve this problem. The corporations will have to decide on the transit method from the manufacturer to the school store. The corporations will trace their route on a map.

The corporations will have to estimate the following: the volume of their packaging material, the volume of the cargo space of each mode of transit (plane, train, tractor

trailer), the number of miles traveled for each mode of transit, the carbon emission for each mode of transit.

The corporations will have to calculate the following: the number of packaged phones that can fit into each mode of transit and the number of trips each mode of transit would have to make to transport the total number of phones sold.

Homework:

Write a persuasive essay to your corporation in order to carry out your carbon emission reduction idea.

Exit Ticket:

How could you reduce your corporation's carbon emissions?

Lesson 9: Useful Life

Objectives:

- Students will be able to estimate the useful life of their cell phone.
- Students will be able to estimate the number of Joules that their cell phone uses in a year.

Materials:

- Lesson activity sheet - (goo.gl/6kkgAE)

Do Now:

Estimate the number of days you have had your own personal cell phone.

Instruction:

Teacher will review the useful life stage of the life cycle. Students will then research the average lifespan of their corporation's phone. The FERMI problem presented for this stage is: How much energy is used during the lifespan of your cell phone?

Homework:

If one food calorie equals 4,184 joules of energy and you take in at 2,000 calories a day, how many days would you need to give up to equal the amount of energy used during the lifespan of your cell phone?

Exit Ticket:

Calculate the total amount of energy used by all of your brand's cell phones in 2014.

Lesson 10: End-of-Life

Objectives:

- Students will be able to explain what can happen to old cell phones.
- Students will be able to estimate the amount of waste created by the disposal of cell phones.

Materials:

- Computer (1 per corporation)
- Lesson activity sheet – (goo.gl/2RPo2v)

Do Now:

Do you have any old cell phones (or other electronics) at home that you don't use anymore? What do you plan to do with those items?

Instruction:

Teacher will review the end-of-life stage of the life cycle. The map from the United Nations Environmental Programme's Basel Action Network will be re-displayed (from *Lesson 1*) that shows the "Known and Suspected Routes of e-waste Dumping." This map can be found at http://worldloop.org/e-waste/illegal-flows/. The FERMI problem presented for this stage is: How many pounds of gold will end up in a landfill next year from all of your cell phones sold in 2014?

Homework:

Write an expository review of this unit. What did you absolutely love? What could you have lived without?

Exit Ticket:

If you were allowed to collect all that gold, what would you do with it?

Annotated Bibliography/Resources

Reading List for Teachers

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The Teacher Toolkit. “Guided Notes.” Retrieved May 2015 from http://www.theteachertoolkit.com/
A fantastic shared resource for teachers.

Underwriters Laboratories, Inc. “The Life Cycle of Materials in Mobile Phones.” 2011 Retrieved May 2015 from http://services.ul.com/wp-content/uploads/sites/4/2014/05/ULE_CellPhone_White_Paper_V2.pdf
Contains an advanced break down of the life cycle of materials in cell phones.

United States Environmental Protection Agency. “The Life Cycle of a Cell Phone.” Retrieved May 2015 from http://www.epa.gov/osw/education/pdfs/life-cell.pdf
Used as the model life cycle of a cell phone, background information taken from source.

Reading List for Students

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Provides interesting cell phone recycling statistics

Compare Camp. “How & Where iPhone is Made: Comparison of Apple’s Manufacturing Process.” September 17, 2014. Retrieved May 2015 from http://comparecamp.com/how-where-iphone-is-made-comparison-of-apples-manufacturing-process/
An infographic that shows a global supply chain of where the iPhone is made

Rockwood, Kate. “How a Handful of Countries Control the Earth’s Most Precious Materials.” November 2010. Retrieved May 2015 from http://www.fastcompany.com/1694164/how-handful-countries-control-earths-most-precious-materials
Simple and visual break down cell phone raw material locations statistically by countries

List of Materials for Classroom Use

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Used in Lesson 5 for the interactive webquest explaining the processing of crude oil.

World Loop. "Illegal Flows." Retrieved May 2015 from http://worldloop.org/e-waste/illegal-flows/
Use for the map that shows the known and suspected routes of e-waste dumping.

Appendix/Content Standards

Next Generation Science Standards (http://www.nextgenscience.org/)

HS-PS3-1

Create a computational model or simulation of a phenomenon, designed device, process, or system.

HS-PS3-2

Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

HS-PS3-3

Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

HS-PS3-4

Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Pennsylvania Common Core State Standards (http://www.pdesas.org/Standard/PACore)

CC.3.5.9-10.A.

Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

CC.3.5.9-10.B.

Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

CC.3.5.9-10.G.

Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

CC.3.5.9-10.I.

Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

CC.3.6.9-10.C.

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

CC.3.6.9-10.E.

Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.

CC.3.6.9-10.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.3.6.9-10.G.

Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

CC.3.6.9-10.H.

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