STEM Lesson Planning Guide

This instructional design guide serves as the template for the design and development of STEM units of instruction at the Dayton Regional STEM Center in Dayton, Ohio. The guide is anchored to the *STEM Education Quality Framework* also developed at the Dayton Regional STEM Center.

STEM Unit Title	**Reinvention: From Rubbish to Recyclable**
Economic Cluster	Environmental Engineering
Targeted Grades	9th Grade Physical Science
STEM Disciplines	Science Technology Engineering Math
Non-STEM Disciplines	Fine Arts English Language Arts

Section I: Learning Experience Overview

Timeframe

Day 1: 50 minutes
Pre-Test and Investigate Physical Properties of Substances

Day 2: 50 minutes
Establishing a Mixture Separation Plan

Days 3 and 4: 100 minutes
Separating a Mixture

Days 5 and 6: 100 minutes
Writing a Patent Proposal

Day 7: 50 minutes
Shark Tank Presentation Preparation Day

Day 8: 50 minutes
Shark Tank Presentations and Post-Test

Engineering Design Challenge

In 1980, approximately 150 million tons of trash was created in the U.S., and less than 10% was recycled. In 2012, more than 250 million tons was generated, but approximately 30% was recycled. As landfills continue to approach capacity, many waste management companies have found it can be profitable to recycle material as well. Unfortunately, this often requires labor-intensive (and expensive) sorting and filtering techniques, meaning smart and efficient filtering designs are in high demand. In the experimental phase of this project, the team members will investigate how different materials (e.g., salt, sand, metal) can be effectively filtered from a heterogeneous mixture. This will require the students to carefully plan and implement a design based upon mechanical and physical separation techniques. Based on the knowledge they gain in the experimental phase, the student teams will then use the engineering design process to design a “real-world” filtering machine to autonomously and efficiently filter the same heterogeneous mixture. The goal of this machine will be to allow the valuable materials to be easily recovered, without excessive loss or contamination. The students will communicate their design by submitting a modified patent application form, containing a well written technical paper and a clear engineering schematic.

Essential Question

Utilizing properties of matter, how can a system be designed to separate and classify various substances found in a given mixture?

Enduring Understanding

Humans create more garbage than is recycled or reused. As a result, landfills are growing in size and number worldwide, many of which are approaching capacity. This presents a significant risk to Earth’s environment as we know it. Though recycling infrastructure and participation have grown around the world, there is still room for growth and improvement, providing both environmental and economic benefits. One major challenge of the modern recycling industry is the difficulty in sorting all different types of materials, which limits what can be collected and recycled. Improvements in sorting technology and processes will enhance industrial recycling capability and enable an overall increase in recycling capacity, thus reducing the percentage of garbage deposited in landfills around the world. A firm understanding of classification of matter must be incorporated with measurement and separation techniques to enable improvements in sorting technology and processes.

Objectives

Day 1:
Students will observe each sample of material, discuss possible testable properties (e.g. state of matter, color, size, shape, odor), then test and record their findings for each material in a data table.

Day 2:
Students will develop a written plan to separate a “barrel” containing a mixture of materials from Day 1. The plan must include separation technique and order of separation. The materials must be in a solid, dry form for lab completion, and the barrel cannot be opened until the plan is approved and testing begins.

Days 3 and 4:

Students will physically separate the mixture according to their plan. Students will reflect on steps and materials needed to separate matter. Students will calculate and graph volume, density, and percent mass of each material in mixture.

Days 5 and 6:
Students will complete a patent application for their no-touch separation device. The application will include written descriptions of the device and a detailed drawing.

Day 7:
Students will watch short Shark Tank clip, then have time to develop responses to Shark Tank panel question list.

Day 8:
Students will present no-touch separation device patent to class in a Shark Tank-style panel forum.

Academic Content Standards

Pre-requisite Knowledge & Skill (as connected to academic content and standards)	Physical Properties, Chemical Properties, Safety Protocols, Density, Water Displacement Method, Qualitative Data, Quantitative Data

Add Standard	**Mathematics**	
Grade/Conceptual Category	Reason quantitatively and use units to solve problems	
Domain	Number and Quantity	
Cluster	Quantities	
Standards	HSN.Q.A.1 - Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. HSN.Q.A.2 - Define appropriate quantities for the purpose of descriptive modeling. HSN.Q.A.3 - Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	

Add Standard	English Language Arts	
Grade	9-10	
Strand	Writing	
Topic	ELA-Literacy W.9-10.2.A-F	
Standard	Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content. CCSS.ELA-LITERACY.W.9-10.2.A Introduce a topic; organize complex ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. CCSS.ELA-LITERACY.W.9-10.2.B Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. CCSS.ELA-LITERACY.W.9-10.2.C Use appropriate and varied transitions to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. CCSS.ELA-LITERACY.W.9-10.2.D Use precise language and domain-specific vocabulary to manage the complexity of the topic. CCSS.ELA-LITERACY.W.9-10.2.E Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. CCSS.ELA-LITERACY.W.9-10.2.F Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).	

Add Standard	Social Studies	Ohio
Grade		
Theme		
Strand (pk-8 only)		
Topic		
Content Standard		

Add Standard	Science	Ohio
Grade	Physical Science	
Theme	Study of Matter	
Topic	Classification of Matter	
Content Standard	Matter can be classified in broad categories such as homogeneous and heterogeneous or classified according to its composition or by its chemical (reactivity) and physical properties (e.g., color, solubility, odor, hardness, density, conductivity, melting point and boiling point, viscosity and malleability). Solutions are homogenous mixtures of a solute dissolved in a solvent. The amount of a solid solute that can dissolve in a solvent generally increases as the temperature increases since the particles have more kinetic energy to overcome the attractive forces between them. Water is often used as a solvent since so many substances will dissolve in water. Physical properties can be used to separate the substances in mixtures, including solutions.	

Add Standard	Science	Ohio
Strand		
Course Content		
Content Elaboration		

Add Standard	Fine Arts	Ohio
Enduring Understanding		
Progress Points		
Grade Level	High School Beginning	
Content Statement	6PE - Describe the decisions made in the design of everyday objects.	

Section II: Lesson Plan

Instructional Process

Teacher Notes

Day 1: Investigate Properties of Each Substance

1. Administer the Pre-Test Appendix A

2. Students should be grouped in teams of four.

3. Provide a 5-gram sample of each of the substances unless otherwise noted (aluminum, camphor, polystyrene (2 grams), sand, salt, and steel BB's) in a clearly labeled container to each team.

4. As a class, discuss physical and chemical properties that may be tested (state of matter, color, particle size, shape, odor, magnetism, static attraction, mass, volume, density, conductivity, and solubility.) Create a data table as a class or use the prepared table found in Appendix B

5. Each team of four will subdivide into two-partner sets. Each team of two will work on their own set of three substances and then collaborate to share the results of their investigations with the rest of their team.

6. Students should complete their data charts by highlighting any quantitative data that they have collected.

7. Complete the Lab Performance Rubric Appendix C

Day 2. : Establish the Plan to Separate the Mixture

1. Students are given a clear container filled with recyclable mixture that they must separate. See Materials List for composition.

2. Teams must develop a written plan to separate the mixture of the substances into containers. Students may not open the mixture in the planning process, and the mixture must be in a solid, dry state at the conclusion of the separation.

3. The plan must include the techniques as well as equipment needed, listed in order of use for separating the heterogeneous mixture.

4. Teams must present the plan for approval before testing begins.

5. Complete the Lab Performance Rubric Appendix C

Day 3 & 4: Separating the Recyclable Mixture

1. Teams are provided with a container of recyclable mixture and may begin separation as planned on Day 2.

2. As teams completely separate each material in the barrel, they should measure the mass and volume and complete any necessary calculations (density and percent mass) on Math Worksheet. Materials being measured should be as separated as possible from all other materials (i.e. single substance, NOT mixture). Appendix E

3. Using the results in Step 2, students should create a percent mass bar chart for their barrel. Appendix F---Teacher Math Worksheet

4. Differentiation Part I: When students have completed Step 3, they can answer the Qualitative Math Questions. Appendix G

5. Differentiation Part II: When all student groups have completed their mass and volume measurements, the teacher (or advanced student group) should complete a mass versus volume scatter plot for 3 noticeably different materials (i.e. materials with varying densities). The legend should be left blank for students to determine clustering. Appendix F–Teacher Math Worksheet

6. Differentiation Part III: When all student groups have completed their density calculations, the teacher (or advanced student group) should compute the Group Analysis average densities and standard deviations for the average densities. Appendix F–Teacher Math Worksheet

7. Evaluate the student lab performance using Lab Performance Rubric Appendix C

Day 5 & 6: Writing the Patent Proposal

1. Provide students with Patent Packets Appendix H, as well as the Patent Grading Rubric Appendix I

2. Students will choose one of four jobs as part of the patent writing process.

3. Students should be provided with technology to research and prepare their patent proposal.

Day 7: Shark Tank Preparation Day

1. Students will watch short Shark Tank Clip Appendix J

2. Students are then presented a list of the Shark Tank panel questions to compose their responses in preparation of their presentation on Day 8. Appendix K

Day 8: Project Presentation Shark Tank-Style

1. Students will present their no-touch separation device patent to class in a Shark Tank-style panel forum and be graded per the Shark Tank Presentation Rubric Appendix L

2. Students complete Post Test Appendix A

Assessments

Day 1:
Administer the Pre-Test to determine base line knowledge on standards. Appendix A

Days 1-6
As students are working in groups, utilize the Lab Performance Rubric Appendix C

Day 7:
Utilize the Patent Grading Rubric Appendix H

Day 8:
Utilize the Shark Tank Presentation Rubric K
Administer the Post-Test Rubric Appendix A

Materials List

Quantity	Description
	See Appendix L

Digital Resource List

Description	Hyperlink
Ducksters. “Chemistry for Kids: Separating Mixtures.” Retrieved 12 Feb 2015	http://www.ducksters.com/science/chemistry/separating_mixtures.php.
Education.com. “Separating Mixtures.” Retrieved 12 Feb 2015 To explore the different properties of matter that enable mixtures to be separated. To demonstrate the separation of mixtures through filtration and evaporation.	http://www.education.com/science-fair/article/separating-mixtures/.
Educational Portal. “Chromatography, Distillation and Filtration: Methods of Separating Mixtures.” What are some ways that mixtures can be separated? Watch this video to explore several examples of ways you can separate a mixture into its individual components.	http://education-portal.com/academy/lesson/states-of-matter-and-methods-of-separating-mixtures.html.
General Chemistry Online. “Separating Mixtures.” Components in a mixture retain their identities; exploit properties that distinguish the components to separate mixtures.	http://antoine.frostburg.edu/chem/senese/101/matter/separation.shtml.

Contributed by: National Science Foundation GK-12 and Research Experience for Teachers (RET) Programs, University of Houston. Students learn how to classify materials as mixtures, elements, or compounds and identify the properties of each type. The concept of separation of mixtures is also introduced since nearly every element or compound is found naturally in an impure state such as a mixture of two or more substances, and it is common that chemical engineers use separation techniques to separate mixtures into their individual components. For example, the separation of crude oil into purified hydrocarbons such as natural gas, gasoline, diesel, jet fuel and/or lubricants. Engineering Connection explained.	https://www.teachengineering.org/view_lesson.php?url=collection/uoh_/lessons/uoh_sep_mixtures_less1/uoh_sep_mixtures_less1.xml.

Section III: STEM Career Connections

Career Connections	Career Description
	Analytical Chemist: “Analytical chemists use their knowledge of chemistry, instrumentation, computers, and statistics to solve problems. Analytical chemistry is the science of obtaining, processing, and communicating information about the composition and structure of matter. They conduct basic laboratory research; perform process and product development; design instruments used in analytical analysis; teach; and work in marketing and law.” Chemists “operate complex instruments to analyze the chemical and physical properties of various substances. Common instruments that you might use include high-performance liquid chromatography (HPLC) instruments, mass spectrometers, microscopes and nuclear magnetic resonance (NMR) machines.” (Learn.org). The American Chemical Society explains that workers help everyone in society understand material interactions. There are vast arrays of industry departments that rely on the expertise of a well trained material analyst. “Major industrial customers include rubber and plastic products, textiles, apparel, petroleum refining, pulp and paper, and primary metals. Consumer products companies make consumer products for everyday use, such as soaps, detergents, cleaning products, plastic goods, and personal care products.” (American Chemical Society). Alternatively, an employee might work in Agriculture and Food to “perform tests and analyses to ensure product quality and stability, develop assays, and troubleshoot and repair instrumentation” (American Chemical Society). In addition, a career in any of the following would also utilize the strong laboratory skills of the Chemist needed for communicating data in “Forensic Labs, Oil and Petroleum, Universities and Government Laboratories” (American Chemical Society), and the pharmaceutical industry, which “develops, produces, and markets drugs licensed for use as medications for humans or animals.” (American Chemical Society).
	Civil Engineer The United States Bureau of Labor Statistics summaries the extent of roles civil engineers fill to “design, construct, supervise, operate, and maintain large construction projects and systems, including roads, buildings, airports, tunnels, dams, bridges, and systems for water supply and sewage treatment.” Civil engineers typically work on multidisciplinary teams which can include other mechanical, electrical, or structural engineers as well as other professional consultants such as architects, accountants, and systems analysts. On a daily basis, civil engineers perform a number of activities such as “Analyze survey reports, maps, and other data to plan projects; Consider construction costs, government regulations, potential environmental hazards, and other factors in planning stages and risk analysis; Perform or oversee soil testing to determine the adequacy and strength of foundations; Test building materials, such as concrete, asphalt, or steel, for use in particular projects; Provide cost estimates for materials, equipment, or labor to determine a project’s economic feasibility; Use design software to plan and design transportation systems, hydraulic systems, and structures in line with industry and government standards; Perform or oversee, surveying operations to establish reference points, grades, and elevations to guide construction; and Manage the repair, maintenance, and replacement of public and private infrastructure.” (U.S. Bureau of Labor Statistics, U.S. Department of Labor).

Systems Engineer
The International Council on Systems Engineering (ICOSE) defines system engineering as “an interdisciplinary approach and means to enable the realization of successful systems” that “focuses on defining customer needs and required functionality” and generally analyzes operations, cost and schedule, performance, training and support, testing, disposal, and manufacturing. To further explain the engineering design process that encapsulates the common steps systems engineers utilize to achieve project success, the ICOSE Fellows agree on the following cycle: “State the problem, Investigate alternatives, Model the system, Integrate, Launch the system, Assess performance, and Re-evaluate.” (A Consensus of ICOSE Fellows) By focusing on these processes for all components within a system and assessing the problem from multiple viewpoints, a systems engineer provides guidance that optimizes achieving measurable objectives.

Toxicologist
Where the Analytical Chemist determines the structure of matter, a Toxicologist applies this material information to prevent deadly consequences. The Society of Toxicology indicates Toxicologists are responsible to “Develop new and better ways to determine the potential harmful effects of chemical and physical agents and the amount (dosage) that will cause these effects. An essential part of this is to learn more about the basic molecular, biochemical and cellular processes responsible for diseases caused by exposure to chemical or physical substances; Design and carry out carefully controlled studies of specific chemicals of social and economic importance to determine the conditions under which they can be used safely; assess the probability, or likelihood, that particular chemicals, processes or situations present a significant risk to human health and/or the environment, and assist in the establishment of rules and regulations aimed at protecting and preserving human health and the environment.” The means and methods employed to study and assess these affects vary by industry. “There are many subspecialty areas in toxicology research: chemical carcinogenesis, reproductive and developmental toxicology, neurotoxicology, immunotoxicology, inhalation toxicology, risk assessment, and many others. Researchers use laboratory animals, human and animal cells in culture, and other test systems to examine the cellular, biochemical and molecular processes underlying toxic responses.” (Society of Toxicology)

Environmental Engineers:
The National Science Foundation operates programs to assist environmental engineers on furthering the study of human interactions with our environment. Environmental engineers employ “engineering principles to avoid or minimize solid, liquid, and gaseous discharges, resulting from human activity, in land, inland and coastal waters, and air, while promoting resource and energy conservation and recovery. The program also fosters cutting-edge scientific research for identifying, evaluating, and monitoring the waste assimilative capacity of the natural environment and for removing or reducing contaminants from polluted air, water, and soils” (National Science Foundation).

Waste Removal Company:
Waste management systems require trained and sometimes certified technicians to properly dispose of waste. From basic everyday personal waste up to hazardous waste, waste removal companies specialize in following all Federal, State, and Local laws and regulations set forth for protecting the general public from health issues that could result from improperly disposed of materials. The United States Environmental Protection Agency (EPA) mandates many of the requirements for hazardous material containment and disposal, but local ordinances such as water protection zones, also govern processes for disposal of debris. Waste removal companies hire individuals who administer these procedures and maintain documentation indicating methods were executed properly to the standards of the governing codes. The EPA defines some of these required procedures as follows:
"-Label each tank with the words 'HAZARDOUS WASTE' and the date that the waste was generated.
-Store only waste that will not cause the tank or the inner liner of the tank to rupture, leak, corrode, or fail.
-Equip tanks that have an automatic waste feed with a waste feed cutoff system, or a bypass system for use in the event of a leak or overflow.
-Inspect discharge control and monitoring equipment and the level of waste in uncovered tanks at least once each operating day. Inspect the tanks and surrounding areas for leaks or other problems (such as corrosion) at least weekly.
-Use the National Fire Protection Association's (NFPA's) buffer zone requirements for covered tanks containing ignitable or reactive wastes. These requirements specify distances considered to be safe buffer zones for various ignitable or reactive wastes. You can reach the NFPA at 617770-3000.
-Do not mix incompatible wastes or materials unless precautions are taken to pre-vent certain hazards.
-Do not place ignitable or reactive wastes in tanks unless certain precautions are taken." (EPA).

Technical Brief

Whether doing lab research or practicing in the field, the work of scientists and engineers sometimes requires separating, classifying, and identifying mixtures of various substances and types of matter. In general, the matter, or substances, that make up these mixtures can be classified in two ways: 1) according to composition and 2) according to state.

A mixture is a physical combination of two or more substances in which the substances retain their original identity. In general, there are two types of mixtures: homogeneous and heterogeneous. A homogenous mixture is a solution with uniform consistency, composition, and properties throughout, whereas a heterogeneous mixture does not have a uniform consistency, composition, or properties. Individual components of a homogenous mixture cannot be readily identified although they can be separated into substances by physical methods. On the other hand, individual components of a heterogeneous mixture can be readily identified, and like a homogenous mixture, a heterogeneous mixture can be separated into substances by physical methods. Both homogeneous and heterogeneous mixtures are composed of different substances. These substances will be either elements or compounds and can be extracted from either type of mixture by physical methods. Physical extraction does not alter the atomic composition of the substance and includes methods such as boiling, evaporation, condensation, freezing, melting, sublimation, and deposition. Physical extraction methods may cause a change in state of the substance, e.g. from solid to liquid to gas, but do not change the chemical identity of the substance.

Elements are the building blocks of the natural world. They can be found in pure form in nature or may be synthesized in a laboratory and cannot be separated by chemical methods into simpler substances as they are already in the simplest possible form. To this date approximately 118 elements have been discovered, each of which are completely unique by definition and are typically identified by a given name and symbol.
A compound is a substance created by the chemical union of two or more elements. Every compound has a definite ratio of elements that is fixed by nature and cannot be changed. When the constituent elements react to form a compound, a new substance is thus formed, and the properties of the resultant compound are distinct

from that of the individual constituent elements. Compounds, like elements, are identified by a given name and symbol – the symbol is composed of a combination of the constituent elements' symbols and also designates the ratio of elements present in the compound. Further, compounds can be separated into elements only by chemical methods. These methods include decomposition and reaction with other substances, which causes a rearrangement of the atoms of the compound. Through this process the atoms that constitute the compound can be separated and isolated as elements. Note that it is the reverse of this process (rearrangement of atoms and change in atomic composition) that forms a compound to begin with.

Now what use is all this information about substances and mixtures? Well, substances (elements and compounds) and mixtures (homogeneous and heterogeneous) account for the classifications of matter as we know it. What is matter? Matter is anything that occupies space and has a mass – almost everything we can think of in our world. Mass is a measurement of the amount of matter in an object, not to be confused with weight. Weight is the measure of gravitational force exerted on an object. When gravity is uniform (e.g. on earth) the weight of an object will not change; thus mass and weight can be used interchangeably. However, when considering different gravitational forces, the weight of an object with a given mass will be different; thus identifying an object by mass (not weight) becomes more meaningful and more important.

In addition to the classifications of matter based on composition as described above, matter can also be classified according to its state. There are three states of matter – solid, liquid, and gas – which are manifested as a result of the arrangement of atoms and molecules of the given matter. In solid state, the atoms and molecules of the matter are tightly bound to one another, giving the solid matter its rigidity. The atoms and/or molecules are so tightly bound together that each atom or molecule prevents its neighbor from moving, aside from relatively miniscule vibrations around its position of equilibrium. Because the attractive forces are very strong in the solid state, solids have definite shapes and volumes and are relatively easily handled.

In liquid state, atoms and/or molecules are less tightly bound than in solids and are thus more free to move around. Attractive forces in liquids are present but weaker than those in solids, and the atoms or molecules in liquids experience some repulsive forces as well. Because of this, liquids have a definite volume but no definite shape – they assume the shape of the container – and can be poured from one container to another.

In gaseous state, the atoms and/or molecules are even further apart or are not bound together at all. There are only repulsive (no attractive) forces between the atoms or molecules. Because the atoms or molecules are so far apart, gases can occupy a large volume and do not have their own shape or volume, but assume that of the container.

Identification of both the state and composition of matter are essential in classifying the matter, and establishing the physical and chemical properties are both very helpful in doing so. Establishing the physical properties is typically simpler than establishing the chemical properties. Some physical properties that can be identified include: color, shape, odor; boiling, melting, and freezing points; mass, volume, and density; solubility, conductivity, and magnetism.

Color, shape, and odor are all identified quite readily through observing and smelling. Boiling, melting, and freezing points can be determined through the measurement of temperature during heating and cooling. Mass can be measured using a scale or balance, and volume can most easily be determined by utilization of a volumetric flask or beaker. If the size and shape of the matter or substance permits, volume may be obtained by measurement of dimensions and calculation of volume. Once mass and volume are determined, the density can be derived through the mathematical relationship between the three properties: density is the quotient of mass/ unit volume.

Solubility can be tested by submerging the matter/substance (called a solute) into a solid, liquid, or gas solvent. Most often the solvent is a liquid, and can be a pure substance or a mixture. If the solute and solvent combine to form a homogenous solution, it can be stated that the matter is soluble in that particular solvent – e.g., table salt (a solute) dissolves in water (the solvent), so the salt is "water-soluble." Solubility depends on physical and chemical properties as well as temperature, pressure, and pH of the solute, solvent, and solution.
The term conductivity may refer to electrical, hydraulic, or thermal conductivity, among others. Electrical conductivity is a measure of a material's ability to conduct an electric current; hydraulic conductivity is a property of a porous material's ability to transmit water; and thermal conductivity is the intensive property (does not change with sample size) of a material that indicates its ability to conduct heat. Magnetism (ferromagnetism) can be tested by holding a magnet to the matter or substance material and determining whether or not the material is attracted to the magnet. If the material is attracted, it is magnetic; if the material is not attracted, it is not

magnetic.

Determination of physical and chemical properties of a matter or substance is very useful and often imperative in the classification and identification of the matter or substance. Once the properties are known, they can be utilized in assisting the separation of a given mixture into its component substances.

Section IV:

References

Online resources:

http://www.docbrown.info/page01/ElCpdMix/EleCmdMix.htm
ELEMENTS, COMPOUNDS, MIXTURE separation, CHEMICAL REACTIONS & EQUATIONS

http://dictionary.reference.com/browse/Mixtures

Analytical Chemistry (n.d.), American Chemical Society, Retrieved February 23, 2015, from http://www.acs.org/content/acs/en/careers/college-to-career/areas-of-chemistry/analytical-chemistry.html

Retrieved February 23, 2015, from http://learn.org/articles/Analytical_Chemist_Career_and_Salary_FAQs.html

What is System Engineering? (n.d.). International Council on Systems Engineering (INCOSE), Retrieved February 23, 2015, from http://www.incose.org/practice/whatissystemseng.aspx

A Consensus of the INCOSE Fellows (n.d.). International Council on Systems Engineering (INCOSE), Retrieved February 23, 2015, from http://www.incose.org/practice/fellowsconsensus.aspx

Summary. (n.d.), U.S. Bureau of Labor Statistics, U.S. Department of Labor, Retrieved February 23, 2015, from http://www.bls.gov/ooh/architecture-and-engineering/civil-engineers.htm

Society of Toxicology. (n.d.). Retrieved February 23, 2015, from http://www.toxicology.org/AI/apt/careerguide.asp

National Science Foundation: Division of Chemical, Bioengineering, Environmental, and Transport Systems: Environmental Engineering (n.d). Retrieved April 26, 2015, from http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=501029

Managing your hazardous waste: A Guide for Small Business, United States Environmental Protection Agency, December 2001, Retrieved April 23, 2015, from http://www.epa.gov/osw/hazard/generation/sqg/handbook/k01005.pdf

Online textbooks:

Poulsen, T. (2010). Introduction to Chemistry. Retrieved 12 Feb 2015 from http://www.openedgroup.org/books/Chemistry.pdf

FHSST Authors. (2003). “The Free High School Science Texts: A Textbook for High School Students Studying Chemistry.” Retreived 12 Feb 2015 from from http://www.nongnu.org/fhsst/fhsstchem.pdf

The Slayer Foundation. General Chemistry - Principles, Patterns and Applications. Retreived 12 Feb 2015 from http://www.saylor.org/site/textbooks/General%20Chemistry%20Principles,%20Patterns,%20and%20Applications.pdf

Science Buddies Staff. (2014 Oct 15). Separating Mixtures: Can You Design a Device to Do It?. Retrieved 12 Feb 2015 from http://www.sciencebuddies.org/science-fair-projects/project_ideas/BioChem_p046.shtml

Curriculum Developers

Margaret Gorby, Contributing Author
Eric Heinrich, Contributing Author
William Johnson, Contributing Author
Amanda King, Contributing Author
Cory Lane, Contributing Author
Carly Monfort, Editor
Deanne Otto, Contributing Author
Donald Smith,Contributing Author

Heidi Steinbrink, Contributing Author, Editor
Michelle Striet, Contributing Author
Stephanie Walter, Contributing Author
Sarah Wallentine, Contributing Author
Maloupu Watts, Contributing Author

List of Appendices