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It's Not Waste: Teaching Recycling through Density, Phase Change and Solubility

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Conservation. Sustainability. Renewable resources. These immense concepts overwhelm my students; even I have difficulty wrapping my mind around them. With such multifaceted ideas, the students find it complicated to act in an earth-friendly manner. Going green is more complex than buy this product and not that; behave in this manner and not that. Thirteen year olds believe that something is either right or wrong. However, being socially responsible is never clear-cut. The rule-oriented thinking of my adolescent students overpowers their capacity to make decisions with respect to degrees of harm and good. In this unit, the students will explore local and simple actions to aid the planet while developing problem-solving skills.

Overview

In the last five years, Delaware has changed from a multi-stream [1] recycling system to a single stream recycling system. Multi-stream recycling requires the recycle-conscious citizens to separate the materials into categories; single stream recycling is sorted at a Material Recovery Facility (MRF). My students are familiar with the general concept of recycling because one of the collection locations is on school property as well as there being an ongoing initiative in our school to recycle waste produced onsite. Nevertheless, the students do not understand what happens to the recycling, the new method of collection for the single stream system and what is acceptable to recycle. Each of these concepts aligns with the state curricular expectations for seventh grade chemistry: density, solubility, and phase change (Appendix A). This unit culminates a four-week study of properties of matter using parts of the STC/MS Properties of Matter kit [2] . This component will take two additional weeks.

The students struggle with the scientific concepts of density, solubility, and phase change because it requires abstract thinking to understand these ideas. At thirteen, only a small percent of students are beginning to think beyond the concrete. The behavior of microscopic particles in matter is often beyond most of my students' comprehension. If they cannot see it with their naked eye, they don't incorporate the concept into their understanding of how matter behaves. Though we draw models, interact with digital graphics, and experiment at the macroscopic level to image abstract or microscopic principles, the students still leave with misconceptions.

The majority of the students cannot get their minds around the idea that all matter is made of particles with space between these particles. They see something without 'holes,' whether solid or liquid and cannot believe that it has a specific degree of packedinedness - density. They are often able to calculate the density but do not tie it to how matter behaves or interacts. It is just some unconnected math problem. They do not tie the concept of density to floating or sinking though we calculate the density of materials and compare it to the density of water. We drop matter of different densities and sizes into a tank of water and watch it sink or float, noting the material's density. At least a handful of my students will complete the unit still stating that objects float or sink because of their size. From there it's all downhill: phase change and solubility hinge on the concept of particles and their interaction with one another. The major misconceptions are that a substance disappears, is consumed, or melts when it dissolves and that matter changes to a completely different substance when it changes phase.

Their misunderstandings are not limited to the scientific concepts but also recycling. Though most schools in our district have recycling programs, students are rarely taught what can and cannot be recycled and why. I watch students place used tissues and Styrofoam trays with food into the recycling receptacles. They do not realize that biological materials cannot be recycled at a MRF. Moreover, they do not question how the objects they discard are changed into material that can be reused.

The chemical and recycling misconceptions can be remediated at the same time. Single stream recycling requires an understanding of density to sort the materials. Solubility is the basis of the reclamation of paper, while phase change is the basis of the reclamation of metals, plastics, and glass. Biological matter contaminates the recycling process and renders much of the stream unusable.

To reinforce the basic characteristics of matter and alleviate mistaken beliefs, students will apply the concepts of density, phase change, and solubility while experimenting with methods of recycling in a single stream system. They will determine how to sort comingled recyclables to prevent contamination and how to reclaim the various materials for reuse. In this unit, students will explore the application of scientific concepts and techniques of investigation, problem-solving strategies, as well as behaviors that will help sustain the environment.

Objectives

The aim of this unit is three fold: to create questioners and lifelong learners, to make an impact on the environment and to influence businesses in our area to act more responsibly.

"Education has for its object the formation of character." [3] Though I have standards to teach (Appendix A), my greatest goal as a teacher is to help raise responsible, capable citizens, not to impart knowledge or skills. Individuals should act not only in their own best interest but also in the interest of others; thus, I must teach empathy and ethics. They should adapt when confronted with new situations; thus, I must teach flexibility and critical thinking. As a teacher, I have no higher calling than to lead students toward their fullest potential as human beings.

Students must not just see their responsibility as only for themselves and other humans but also for the environment in which they live. Through this unit, students develop plans to recycle, mitigating climate change and reducing the pressures on biodiversity. Recycling saves nonrenewable resources and cuts air and water pollution: protecting not only the human inhabitants of this planet but all life and the earth itself. [4]

"The great aim of education is not knowledge, but action." [5] Remediation of our planet can only happen if the students act at home and with the business community. They must insist that businesses have a recycling plan in place for every product. Life cycle management of products is an essential component of production. Resource recovery and end-of-life issues for a product conserve natural resources, provide a cost-effective feedstock, create jobs, [6] and build more competitive industries. [7] For example, polyethylene tetra phthalate (PET) bottles were introduced in 1978. Only one year after the introduction, eight million bottles were recycled. Disposable societies do not lead to sustainability of a company, the planet, or the human race. Through this unit, students will learn what it means to recycle and be an active part of reducing our negative impact on the environment.

Background

Brief History of Recycling

Though recycling was present as far back as prehistoric times, collecting recycle, as we know it, did not begin in the United States until the 1700's. Individuals would solicit townspeople for used scrap paper, metal and clothes which were sold to local manufacturers to make into new products. This was essential when British embargos stopped the importing and exporting of raw materials and finished products to and from the American Colonies. The British only allowed their highly taxed goods to be sold. In response, colonists stopped buying British goods to show their displeasure but then did not have virgin material to make their own goods. Scrap materials were essential in the protest against British imperialism. The demand for scrap diminished as manufacturers imported raw materials after independence from England. The demanded for recycled material declined more as innovations for accessing and processing virgin resources were invented. Newspaper collection appeared briefly in the 1950's but did not last. In the 1980's, the multi-stream system became popular. The first single stream recycling system began in Phoenix, AZ in the early 1990's. By 1997, 4 localities used single stream models, and by 2005 over 95 single stream recycling systems were in place. [8]

Single Stream Recycling

In the single stream model, comingled recyclables are collected in one container from the consumer or at a drop-off center, delivered to a Material Recovery Facility (MRF) where the recyclables are separated, stored and sometimes processed for remanufacturing. [9] This system is preferable to the multi-stream because it costs less, is easier for the consumer, promotes innovations in sorting, requires fewer containers, allows for larger receptacles, simplifies the education of the consumer and increases the rate of recycling [10] . The overall rate Delawareans recycle has increase steadily since the institution of a single stream recycling system and voluntary curbside pickup. [11] Unfortunately, there is an additional cost for sorting the materials and a higher rate of cross-contamination of recyclables. [12] Even with both these drawbacks, single stream recycling systems produce greater rates of collection than a multi-stream system.

In a single stream system, there are two main methods for separating scrap material once it arrives at the MRF: manual or automated. Though manual separation employs more people and reduces the rate of product contamination, automation increases the speed of separation, reduces the cost, and improves the recovery. [13] Human separators reject more plastics than machines because they are not trained to identify all styles and designs of products made from the different typology of plastics (Appendix B). Thus, manual sorters increase the amount of recyclables that end up in landfills, but their recovered product is cleaner. Because the separation process is also beset with dangerous biological and chemical contaminants from the products and the process, automation is safer for employees. [14]

In the mechanized system, the collection trucks dump the comingled recyclables onto a tipping floor where it is lifted onto a conveyer belt and multiple processes sort into ferrous and nonferrous metal, plastics (by typology), glass, paper products and cardboard streams. Different MRFs are set up to separate materials in different orders: there is no set industrial standard. An electromagnet removes ferrous metals from the stream because they are magnetic. An eddy current produces an electric field that repels and propels the nonmagnetic, nonferrous metals into another bin. Paper and cardboard are sorted manually, with air classification or trommels. Trommels [15] and air classification [16] use density to classify paper and cardboard from the more dense plastic and glass. Plastics, as a whole, are often separated manually, but they cannot be sold until they are separated by typology. [17] Glass usually remains after everything else is sorted out. Recyclables can be shredded, ground, milled, cleaned, and baled before being sold to remanufacturers [18] (Appendix C for recent prices of recycled materials; daily price updated on http://www.scrapindex.com/). Specialized distributers or remanufacturing plants use the process of phase change to produce new materials from recyclables. A locality may not collect and recycle a particle type of recyclable material because it is not profitable (Appendix D for a list of the recyclables Delaware Solid Waste Authority collects).

Separation of Plastics

"Separating different plastics and finding uses for mixed plastics are major recycling challenges." [19] Plastics are rarely sold or remanufactured without typology separation (Appendix B for typology classification system). If different types of plastics mix, harmful chemicals may form when they are melted potentially destroying equipment and producing an unusable product. For example, when PET is mixed with polyvinyl chloride (PVC), hydrochloric acid is released. [20] Therefore, MRFs must carefully separate the typology once the plastics are removed from the single stream.

Facilities employ various methods to sort plastics: manual, infrared/sensor detection, and density separation. Manual sorting requires identification training. Because of bottle shape and color diversity, manual identification and sorting leads to high rates of rejection of recyclable materials. Materials that cannot be recycled end up in a landfill. On the other hand, detection systems misclassify plastics more often than manual sorting. They require recyclables to pass individually below the device with caps and labels removed or the sensor will misread the type of material and misdirect the recyclable. [21] Two systems of identification must operate simultaneously to compensate for colored plastics sending false reads to the infrared sensors.

Density separation systems are more cost-effective, flexible, widely used and process a higher capacity of material than the manual or detection systems. [22] There are two main density systems: centrifugal machines and sink-float tanks. Both practices use the relative buoyancy between the densities of the plastics to sort in a liquid separating media. These media include water, ethanol or solutions containing ethanol, $Ca(NO_3)_2$, NaCl, $CaCl_2$ or $ZnCl_2$. Both methods are accurate to plus or minus 0.01 g/cm^3 . Centrifugal machines use centrifugal force in an inclined conical tank to speed the separation of densities through the sorting medium. [23] The separating medium's movement forces the less dense material to the center of the vortex, up through an overflow opening; while the medium pushes the denser material toward the outside of the vortex, and forces it through the apex. [24] Since gravity is the only force in the sink-float tanks, the process is much slower but can accommodate much more material. [25] These sink-float systems can process one to two thousand pounds an hour at 1/30 th the cost. [26]

In the static system, the hydrophobic properties of plastic are more of a problem. Even if the plastic is denser than the water or solution with a water solvent, the plastic tends to float. Air bubbles often adhere to the polymers and decrease the density causing plastics to be incorrectly sorted. Placing the plastic in the separating medium instead of on top or pouring the medium onto the plastic helps alleviate this problem. [27] A three-bath system is most commonly used in the sink-float method: first plain tap water, second 50% by volume ethyl alcohol and third 30% by weight calcium chloride. This provides a partial separation of plastic types. Unfortunately, many different plastics share the same range of densities (Appendix B); therefore, both float or sink in a separating medium. Wetting agents, the pH of the medium, electrolytes and frothers can be selected to make one type of plastic hydrophilic. Then the two plastics behave differently: the non-polar, bubble-attracting, hydrophobic plastic will float while the hydrophilic plastic will sink. [28]

The downside to this method is the recovery of separation media. With the additives, the media may be toxic, explosive and react with any residual adhesives left when labels are cleaned off the surface of the plastics. [29] For the density sorting process to be more environmentally friendly, the separation media must be reused, recycled or processed into biodegradable, nontoxic components with the least amount of waste to add to the landfill.

Recycling Paper

Paper is recycled more than plastic, glass and metal combined. While extensive plastic recycling began in 1978 with PET bottles, paper recycling began circa 200 B.C.E. in China. Currently 1/3 of all fibers in paper are recycled. The United States recycles 50% of the paper used. Unfortunately paper degrades more quickly than any of the other recyclables: it can only be recycled five to seven times before the cellulosic fibers become too short and brittle to use. [30] Hence the process of paper recycling must be as gentle as possible to ensure the longest possible use of the fibers.

Deinking

The most caustic process in paper recycling is deinking. After the paper arrives at the mill, it is chopped, mixed with water and chemicals and heated. "Pulping" breaks the sheets of paper into cellulose fibers. [31] Cellulose is not soluble in the chemical solution. The resulting mixture is called pulp. The fibers still hold the ink used for printing. First the ink must be separated from the cellulose strands, often using a surfactant. Then the resulting ink and solvent globules are stuck together with a chemical collector. Lastly a frother is added to link the ink solution to air bubbles. [32]

The ink solvents are the most damaging of the chemicals. Sodium hydroxide (NaOH, or lye) is commonly used. [33] This is commercially available through garden centers at 80% concentration and can be used in the home and classroom but should be treated with great care since it is corrosive to living things. Another type of collector is soap (ethoxylated linear alcohols, ethoxylated alkylphenols, ethoxylated fatty acids, oligoethylene [glycol], oxide alkyl ether, and polyethylene oxide alkyl ether). Surfactants are less frequently used. They are not as effective for removing the ink from the cellulosic strands but do not damage the paper as much. [34]

Experiments combining surfactants and enzymes (cellulases and xylanases) from plant consuming microbes, such as fungi, bacteria and protozoans, remove more ink than surfactants alone. The combination is more cost-effective. [35] Mechanical methods, such as magnetic/electric fields and ultrasonic radiation, are least effective. [36] Though these processes are less damaging to the strands and the environment, they will not be used until they are more effective.

Separation of mixture

Using surfactants or lye, the cellulose is suspended in a solution of water, ink, separators, collectors and frothers (bubble floatation units). To separate the ink and other chemicals from the pulp, air is added. The ink and the solvents are attracted to the surface of the air bubbles, the coated bubbles are less dense than the water, and they float to the top to be skimmed off. [37] The deinking waste can be burned as a fuel, composted or placed in a landfill depending upon the chemicals used. Typically, 50 tons of scrap paper produces 17.5 tons of waste including ink, solvents, glue, and fibers (too small or weak to reuse). The pulp is separated from the suspension through a series of screens to remove any impurities and then water is removed by evaporation. [38] Since the pulp is not soluble in water, filters are usually used to dewater the pulp. Unfortunately, paper fibers act like a sponge and hold water, requiring heat to speed the evaporation/drying process. Thus, the process of separating soluble and insoluble material results in recycled paper.

The process of making paper and reforming plastics, glass and metal are not done at the MRF, but they are all part of the cycle to reclaim recyclable materials. To produce products, the scientific concepts of density, phase change and solubility are particularly important. Therefore, teaching students about the cycle not only leads them into responsible citizenship, but also increases their scientific knowledge.

Strategies

My students have learned the dire environmental consequences they are facing. Images of extinct animals, deforested land, overflowing landfills and contaminated waterways overwhelm them and result in learned helplessness and worse, hopelessness. I must approach environmental education carefully, teaching students to respect their environment. Dr. Brad Smith, Director of the Environmental Education Division of the EPA in 1993, understood the need to guide the students toward responsibility instead of terrifying them into action.

> It's important that students learn about the environment through respect, empowerment and concern - not doomsday issues. Respect, empowerment and concern are issues that transcend the environment, that go deeper than recycling aluminum cans! [39]

Knowledge is not the end all and be all of education. Advances in technology allow access to any fact or opinion anytime, anywhere at the flick of a finger. Students must learn to acquire knowledge, evaluate it, apply it in a variety of ways, and synthesize new understandings and approaches. Constructivism and, closely related, problem-based learning teach students to be doers and thinkers and not repositories of knowledge.

Constructivism

The constructivist approach recognizes that learning is not just an active process, but also a social process.

Students work in groups, combining their thoughts and expertise to formulate a common solution. For the final assessment, students work individually because our education system needs a summative grade for each student, but students assimilate ideas from each other while forming their understanding. Not only will they learn by performing experiments, but also by collaborating with one another and by arguing the relevancy of their approach. They compare and examine other students' methods and results. Furthermore, they investigate errors and discuss how to fix them. In order to do all these things, I will present my students with problems with no right answers.

Problem-based Learning

Open-ended questions are the linchpin of the problem-based method. Students are encouraged to use all relevant knowledge and resources to come up with their own solution. In this manner, students become critical thinkers and doers. They "design and conduct investigations with controlled variables to test hypotheses, accurately collect data through the selection and use of tools and techniques appropriate to the investigation, construct tables, diagrams and graphs, showing relationships between two variables, to display and facilitate analysis of data, and form explanations based on accurate and logical analysis of evidence." [40] The last step is the most important: self-evaluation. After the student reaches a solution to the problem, the process is only partially complete. The student must determine if the process and solution were effective, and evaluate the knowledge gained through the experience.

Students may stumble. Problem-based learning is a beautiful, seemingly disorganized mess, but it teaches students to learn. They may get the answer wrong or come up with a ridiculous solution, but protecting students from failure does not empower them, it robs them of their ability to learn from their mistakes and see that a failure is only a failure if they lose hope. "The ultimate result of shielding men from the effects of folly is to fill the world with fools." [41]

Activities

Pre-assessment

To gain a baseline of the students' abilities to apply the scientific concepts from the previous unit about density, phase change, and solubility, students will be given a mixture of dark drink powder, small wax shavings, iron filings and zinc granules and asked to separate the mixture and describe the properties of the components. The students will have access to beakers, plastic bag covered magnets, water, tweezers, a thermometer, ice and an electronic balance. Some of the materials are not necessary and in the mix as spoilers so that the tools provided do not lead the students to the conclusion. Each student will have to come up with their own procedures and document their actions and findings. The procedures documented and properties of the materials described to show how much the students understand the use of density, solubility, and insolubility to separate materials.

For homework, the students will record their actions to save the environment. Showing how much they already contribute to the single stream recycling effort in Delaware and will apply the lessons learned to our next unit of study: Watersheds.

Responsible Citizenship and Inquiring Minds

Focus Question: What am I doing to save the environment? What happens as a result of my actions (particularly in the area of recycling)?

To catch the student's attention, I will enter the room in a white sheet hanging over my clothes like a toga with cans, papers, and plastic pinned to it and dark marks smeared in places. On my head will be a ring of plastic ivy. On my face, I will also have a dark mark. In a cheerful, but slightly raspy voice, I will introduce myself as Mother Earth and ask the students to share with me the things they are doing to help me since I provide so much for them. Documenting their actions on the board, I expect that they will mention recycling almost immediately because we recycle in our classroom. After the students have exhausted their accomplishments, we will discuss the ways in which their actions help Mother Earth. I will ask them to explain the consequences of the choices they made. I will leave recycling to last. In my class, we are lucky enough to have an interactive white board. Starting a new page, we can use it as a reference as we learn about single stream recycling. This can also be done on a large sheet of paper and posted in the room. I will assess what knowledge the class has about what happens to the materials they recycle. I will question every step and write down their hypothesis and prior knowledge whether correct or not.

To conclude this lesson, I will show them the Introduction video on www.explorethecycle.com. It is only 50 seconds long. Like all videos in my classroom, we will watch it multiple times, so students can have a chance to take in the video as a whole and enjoy the content and then focus on specific components when they re-view. This is similar to the rereading strategy promoted to improve comprehension. The exit ticket for this lesson is to write three things important in the video, two behaviors the student thinks they might want to try to help the environment and one behavior they already do to save the environment. Though I asked for some of this information in the previous night's assignment, the rate for homework completion for most of my students is horrendous, so to get information from all students I require them to write it in class. The previous night's assignment was to start them thinking so they would have something to contribute when I asked for their environmental actions in class.

Plastics Density Separation

Focus Question: If we throw everything into one large pile, how can it then be separated to be reused?

To catch the students attention, I will enter the room with 8 trash bags (the number of lab groups I have) full of cleaned waste to be recycled. Caution: sterilize the recyclables and watch for exposed sharp edges on open metal cans. I will dump one on each lab table and ask the students what do we do with the comingled recyclables that have been brought to the MRF? The class will hypothesize solutions. With a little guidance, the first conclusion needs to be that separating the materials makes them valuable to companies who need them. After that conclusion, list all possibilities on the board. Take this time to brainstorm, not to evaluate. I will make the students explain their methods in some detail. If the students mention automation or machines, I ask them how a machine could tell the materials apart? What would the machine do to distinguish and move one type of material and not another? Next we will discuss the advantages and disadvantages of each option. For example, the obvious solution is to have someone pick through and separate the different types into bins. An advantage to this process is the ease to initiate the program: just hire a few people and get to work. A disadvantage is the material arriving at the MRF is not clean, though the samples in front of the students will be. There are health safety issues with using manpower. Additionally, manpower can only go so fast, and it is expensive over time: health insurance, pensions, not to mention paying numerous employees every week.

After the students have gone through their idea list, I will help guide them to the conclusion that a products specific properties identify what it is made of. I will show the students the second section of www.explorethecycle.com video "MRF." I will stop the video at 31 seconds and ask the students how the v-screen separation works. I will replay the video from the 10 second to the 31 second mark as often as they need. The answer is density. With the students help I will list what is left in the stream and what might work with the next material, steel, iron and tin cans. We will watch the video from the 31 second mark to the 1:03 mark and discuss what was used for both the ferrous and the nonferrous metals. Again we will watch the video as often as necessary. I will have the students note that the property used for the metals was not density but magnetism and reaction to an electrical field. We will start to make a list of the properties. We will watch the rest of the MRF video and I will describe to the students that the sensor that detects the plastics is a combination of infrared sensor and optic sensor. The infrared sensor often misidentifies plastics as other materials because of the coloring of the plastic and any labels or caps left on the bottles. The optic sensor compensates for this deficiency but does not operate well alone either. However, the combination is effective. We will discuss the properties used to separate the plastics and the glass (more dense, not magnetic, does not react to electricity or infrared energy). We will add them to the list and review the ways the students suggested for separation and point out that though the video only detailed one option, there are many systems available.

Then we will watch the plastic segment of www.explorethecycle.com. I will make sure to stop at the 15 second mark and explore the different types of commonly available plastics. I will note that the video does not tell how the machine separated one type from another. After the video, we will clear the recyclables off the table, and I will give the students a container of mixed polymer pellets. [42] If you make your own mix, make sure the densities of the plastics do not fall in the exact same range and that the different types of plastics are different colors. This still allows the students to use manual separation as an option and to discuss the difficulties of the process. I will explain to the students that their task is to separate all the plastic pellets they were given into groups. They must document the exact process they use and record their results. I will offer the students beakers, tweezers, mini-cups, water, salt, magnets, and flashlights. Most likely the students will not finish planning the separation and their experiment will carry over to a second day.

Plastic pellets are hydrophobic and attract air bubbles; so if students use the property of density to separate, some pellets will continue to float despite having a greater density than the water. I will help the students explore ways to deal with this problem. Some suggestions are agitate the water, gently poke all the floating pellets at the surface, or pour the water over the plastics rather than pour the plastics into the water. I will encourage the students to note all the things they try and their success. Close to the end of the second class, whether the students have successfully completed the task or not, we will stop and discuss the students' choices and their results. We will make sure to discuss the advantages and disadvantages of the chosen systems and chart them with the students. At the end of the period, students will write about properties of the plastic pellets and which properties they used to separate the material.

Phase Change: Reading the Graph

Focus Question: How do old cans, bottles and jars become new materials?

For this lesson, students will watch the plastic, glass and metal sections of www.explorethecycle.com determining how the processes are similar. Then they will determine the temperatures at which aluminum, tin, iron and steel change phase using graphs (see Appendix E). Prior to class, I freeze flakes of wax in water. To make the activity more authentic, the water will be frozen in one shape, and I will tell them that I need the ice in another shape, but without the impurities. I will provide beakers, thermometers, hot plates, funnels, filters, and ice trays. The groups with develop procedures and perform their experiment. The last 10 minutes of class, we will discuss the procedures they used and if any problems developed. I expect to see a few groups trying to melt the ice-wax mixture with the hot plates and melting the wax when they only intended to melt the ice. We will discuss how to overcome these difficulties and their exit ticket will be explaining how the lab connected to recycling metal, glass and plastic.

Solubility and Deinking

Focus Question: Why does the ink come off?

In this lesson, students will experiment with different solvents for inks. Using chromatography paper, students will mark on separate papers with an overhead marker, a water-soluble art marker, a permanent marker, ballpoint pen, and dry erase marker. After talking about the properties of chromatography paper, I will offer them possible solvents to try: water, isopropyl alcohol, and hydrogen peroxide. If students make other suggestions, we will try to find them in the building if they are safe to use without a ventilation hood (I don't have one in my classroom). Students will then experiment and document what happens with the methods they choose. The students will stop ten minutes before the end of class to share their results and analyze what happened and why it happened. The exit ticket of the day is to answer the focus question. If students wish to investigate this topic further and suggest other solvents and inks, we may start the class the next day investigating their suggestions.

Insolubility and Papermaking

Focus Question: How is paper recycled? How is the ink separated from the paper? How is an old sheet of paper changed into a clean new sheet?

To focus the class, I will show them some examples of recycled paper (printer grade paper to art paper). We will watch the paper segment on www.explorethecycle.com and discuss the process presented in terms of solubility. The class will then make paper according to the directions on the National Wildlife Federation website, www.nwf.org/forests/papermaking.cfm. The exit ticket will be to draw a cartoon of the papermaking process describing how solubility and insolubility helped separate the ink and the pulp suspension and remake paper. If students cannot finish the assignment, they may turn it in the next day. This lesson will most likely take two days.

Post-assessment and Plan

After completing the unit, I will give the students another mixture and ask them to work independently to separate the components. This mixture will include small pieces of PET milk bottles, iron fillings, powdered tea mix and small pieces of HDPE soda bottles. I will give them the same lab materials as pre-assessment, and they must write out their procedures and document the properties of the materials they find. The post-assessment will be compared to the pre-assessment. The students will reflect in their science notebooks about what they learned.

For homework, they will confer with their families and come up with a signed agreement about what they will do to help the recycling effort. This cannot be an action they already do. As a class, we will come up with possibilities. [43] In this manner, the unit will not just be the acquisition of knowledge and development of critical thinking and investigation but also to increase the students' citizenship.

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Delaware State Standards [44] and Implementation [45] - Appendix A

Analyze a standard phase change graph and identify when the substance is a solid, liquid or gas, as well as freezing/melting point or condensing/evaporating point. Describe increase or decrease of energy in the system. This standard will be met in the recycling metal, glass and plastics lesson. Students will use their understanding of phase change to interpret graphs and separate wax from ice.

Use physical properties to distinguish and separate one substance or material from another. In every lesson in this unit, students will be using the properties of density, melting and boiling points or solubility to separate one substance or material from another.

Distinguish between homogeneous and heterogeneous mixtures. Design and conduct experiments to separate both mixtures. In the paper recycling lessons, students will be separating soluble ink from paper through dissolving and then insoluble paper and water through filtering and evaporation.

Discuss the social, economic, and environmental consequences of the production of new materials to meet human wants and needs. This standard will be met when students develop and put into action plans to help the environment in the post-assessment.

Enduring Understandings are the big ideas that have lasting value beyond the classroom and offer ways of engaging the students: "Scientific inquiry involves asking scientifically-oriented questions, collecting evidence, forming explanations, connecting explanations to scientific knowledge and theory, and communicating and justifying the explanation." [46]

The properties of matter determine their use and guide the selection of the method of problem-solving.

Essential Questions point to the overarching themes in the unit and guide instruction through open-ended questions: "How do the properties of materials determine their use?

How can the properties of the components of a mixture be used to separate the mixture?" [47]

Knowledge essential to understand the big idea: Density, solubility and magnetism are characteristic properties of solids, liquids and gases.

"Density can be used to separate material" [48] through floating and sinking.

"Density, melting points, and boiling points are unique to materials" [49] and can be used to reclaim scrap waste.

"Solutions are homogeneous mixtures of solutes and solvents.

Solubility can be used to separate soluble and insoluble substances.

Components of mixtures can be separated and analyzed by using their physical properties (by filtering, paper chromatography, evaporation, etc.)

Solutes can alter the properties of solvents.

Making materials that behave in certain manners depends upon an understanding of the physical properties of materials." [50]

Skills needed to perform the essential questions: "Recognize that all matter consists of particles and how the particles are arranged determines the physical state. Use the particle model to describe solids, liquids, and gases in terms of the packing and motion of particles.

Begin to distinguish between a "pure" substance and a mixture.

Design and conduct an experiment to separate a suspension," [51] use density to separate a heterogeneous mixture and test solubility using different solutes and solvents.

Typology Classification of Plastics, Density and Examples of Use of Each [52] - Appendix B

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1. Polyethylene tetra phthalate (PET): 1.38-1.39 g/cm ^{3} Soft drink bottles
2. High Density Polyethylene (HDPE): 0.94-0.96 g/cm ^{3} Milk jugs and detergent bottles
3. Vinyl/Polyvinyl Chloride (PVC): 1.20-1.42 g/cm ^{3} Durable construction products
4. Low Density Polyethylene (LDPE): 0.9-0.93 g/cm ^{3} Grocery bags
5. Polypropylene (PP): 0.9-0.91 g/cm ^{3} Durable fibers and diaper liners
6. Polystyrene (PS): 1.05-1.07 g/cm ^{3} Styrofoam

Other common recyclable plastics

Polycarbonate (PC): 1.2 g/cm ^{3} Bulletproof glass and Compact Discs

Acrylonitrile Butadiene Styrene (ABS): 1.02-1.17 g/cm^3 Automotive parts and toys

Market Price of Recycled Items as of July 9, 2009 [53] - Appendix C

Paper: $ 5.74 - 142.50/ton depending upon quality

Steel $ 185.40/ton

Aluminum: $ 380/ton

Glass: $ 1.50 - 24/ton depending how selective the color and processed the glass

Plastics:

- Polyethylene Tetra phthalate (PET), Vinyl/Polyvinyl Chloride (PVC), Low Density Polyethylene (LDPE) or Polypropylene: $ 140/ton

- High Density Polyethylene (HDPE): $ 80/ton

- Polystyrene: $ 220/ton

- Polycarbonate: $ 180/ton

- Acrylonitrile Butadiene Styrene: $ 160/ton

Materials Delaware Solid Waste Authority Collects and Recycles [54] - Appendix D

Newspaper/Brown paper bags

Magazines/Catalogs

Telephone directories/Soft cover books

Junk mail/Envelopes (all types)

Paper

Paperboard (cereal/tissue boxes)

Cardboard

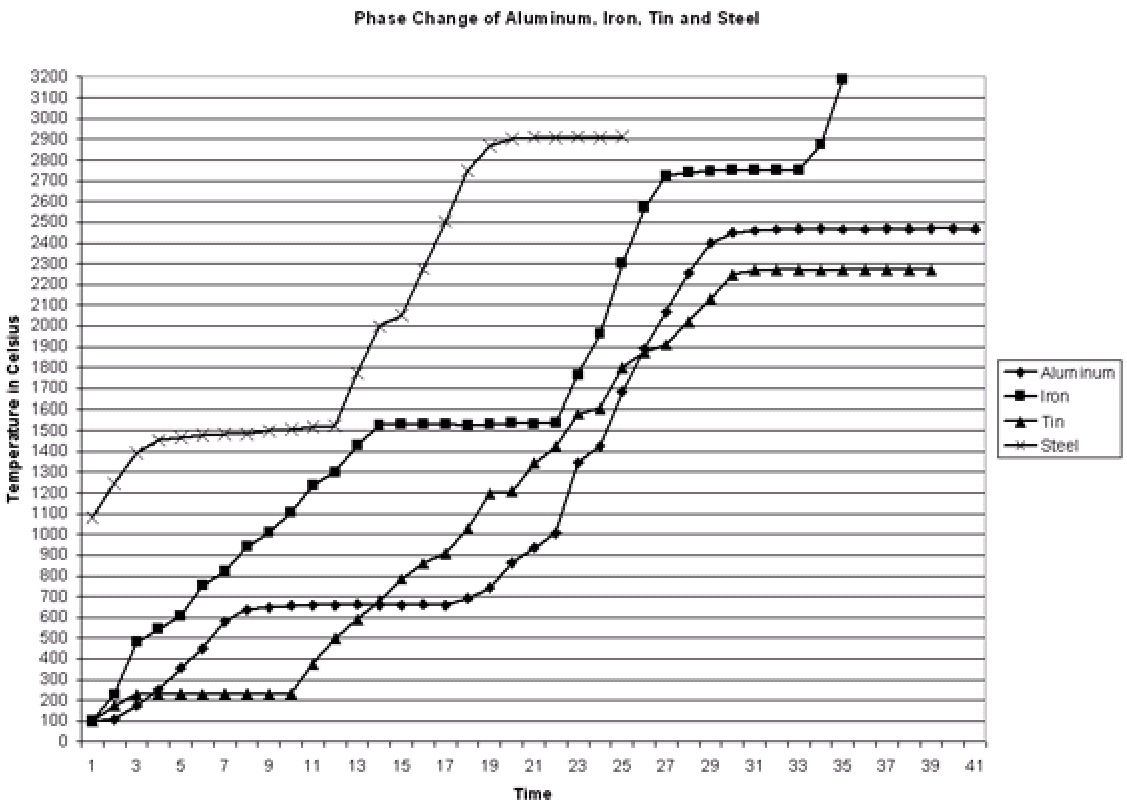
Narrow neck plastic bottles

Plastic grocery bags

Glass bottles/Jars (any color)

Metal cans

Phase Change Graphs for Aluminum, Steel, Iron, and Tin [55] - Appendix E



Endnotes

[1] Delaware required separation of cardboard from other recycled materials for curb pick up and separation of glass, metal, cardboard, newspaper… for individuals delivering materials to recycle stations.

[2] Information concerning the kit and order forms are available at http://www.nsrconline.org/curriculum_resources/STCMS_Physical_science.html

[3] Herbert Spencer, "Herbert Spencer."

[4] One ton of recycled paper saves 380 gallons of oil and 37 trees and produces 74% less air pollution and 35% less water pollution than producing the same amount of virgin paper.

[5] See note 2 above

[6] John Amos, "Cleaning Up the Waste Stream - Recycling Plastics." (hereafter cited "Recycling Plastics")

[7] Alexander J. Dubanowitz, Design of a materials recovery facility (MRF) for processing the recyclable materials of New York City's municipal solid waste.

[8] Tamsin Eltefagh, Overview Effect of Single Stream on Plastics Recycling and Recycling in General

[9] See note 6 above.

[10] In Los Angeles, the amount recycled increased 2 ½ fold when single stream recycling was instituted.

[11] Compilation of the data from the 2004, 2005, 2006, 2007 and 2008 Delaware annual report on waste management (DSWA, "2004 Recycling Report"; DSWA, "The 2005 [12] Annual Report"; Wendy Pizzadili and Sarah Burns, "2006 Annual Report - Delaware Solid Waste Authority"; Wendy Pizzadili, Sarah Burns and Tracy Timson, "2007 Annual Report - Delaware Solid Waste Authority"; Wendy Pizzadili, Sarah Burns and Tracy Cook, "2008 Annual Report - Delaware Solid Waste Authority.")

[12] See note 7 above. Bits of glass, in particular, tend to end up in the other recyclables because they are had to sort out after they break. Alexander J. Dubanowitz tried to alleviate this problem in his design of a MRF for New York City in his master's thesis: Design of a materials recovery facility (MRF) for processing the recyclable materials of New York City's municipal solid waste.

[13] See note 6 above.

[14] Ibid

[15] Trommels are large inclined screws that allow the more dense material to drop to a lower conveyer belt, and the less dense material is carried to an elevated collection bin.

[16] Air classification systems blow the less dense material into bins, leaving the matter with higher densities on the conveyer belt.

[17] The recycling codes on the bottom of plastic containers - See Appendix B.

[18] See note 6 above.

[19] See note 5 above.

[20] Ibid

[21] Ibid

[22] Malcom Richard Gent, Mario Menendez, Javier Torano, and Isidro Diego, "Recycling of Plastic Waste by Density Separation: Prospects for Optimization," in Waste Management & Research.

[23] Ibid

[24] MBA Polymers, Development of Hydrocyclones for use in Plastics Recycling.

[25] See note 21 above.

[26] See note 23 above

[27] Ibid

[28] Sangobtib Pongstabodee, Napatr Kunachitpimol, and Somsak Damronglerd, "Combination of Three-Stage Sink-Float Method and Selective Flotation Technique for Separation of Mixed Post-Consumer Plastic Waste" in Waste Management. (hereafter cited "Separation of Mixed Post-Consumer Plastic Waste")

[29] See note 21 above.

[30] TAPPI, "How is Paper Recycled?"

[31] Ibid

[32] Yulin Zhao, Yulin Deng, and J. Y. Zhu, "Roles of Surfactants in Flotation Deinking" in Progress in Paper Recycling

[33] See note 29 above

[34] See note 31 above.

[35] T. Kent Kirk and Thomas W Jeffries, "Chapter 1 - Roles for Microbial Enzymes in Pulp and Paper Processing" in Enzymes for Pulp and Paper Processing.

[36] See note 31 above; Manendra Doshi, Gary Scott and John Borchardt, "Industry Review Semiannual Conference Review January - June 1995."

[37] Ibid

[38] See note 29 above.

[39] Deborah Houy, "Eco Kids: Green Teens, Not!," 48.

[40] Delaware Department of Education, "Science Content Standards and Grade Level Expectations."

[41] See note 2 above.

[42] I use a prepackaged set available at www.teachersource.com called Mixture Separation Challenge for approximately $ 22. Other than loss from strays falling to the floor, the set is reuseable.

[43] e.g. Using cloth shopping bags, composting, drink from reusable drink containers, use both sides of very paper, donate reusable items, selectively buy items with less packaging (City of San Jose, "Environmental Services), purchase goods that are recyclable, specify preference of recycled items to store managers, recycle electronic equipment (Consumer Reports, "Greener Choices").

[44] See note 39 above.

[45] Delaware Science Coalition, "Grade 7 Properties of Matter Unit Template."

[46] Ibid

[47] Ibid

[48] Ibid

[49] Ibid

[50] Ibid

[51] Ibid

[52] Density comes from "Separation of Mixed Post-Consumer Plastic Waste" Typology and examples come from "Recycling Plastics."

[53] "The Recyclenet Composite Index" in Recyclenet

[54] DSWA, "Single Stream Curbside Recycling."

[55] Yinon Bentor, "Chemical Elements.Com."