USING A STEM-BASED APPROACH TO MAKE RECYCLING METALLIC ELEMENTS RELEVANT

by William Sumrall

Recycling metals is a major business in the United States. Copper, iron, aluminum, and other metals get recycled in various ways. Planned garbage pick-ups, random hauls by individuals to a scrap metal facility, and various organizational recycling of scrap metal (e.g., aluminum can)/clean-up drives are some of the ways metals get reused.

This article describes a series of activities that incorporate multiple subjects, which focus on real-world experiences. Science, Technology, Engineering, and Mathematics (STEM) is an emphasis area, as students are actively involved in understanding some of the costs behind the processes of recycling various metal products. A final classroom-tested activity based on shipping Lincoln pennies for copper reclamation is described in detail.

Activity 1: Building background knowledge

Begin the activity by asking students a series of questions to determine their background knowledge concerning metallic elements. Some sample questions asked in the past are:

- What is a metallic element?
- What are examples of metallic elements?
- How do you determine a metallic element's value?
- Where are metallic elements found?
- What are some by-products of metallic elements? *(You may have to give students a specific example [e.g., an aluminum bat is a by-product of the metallic element aluminum] to gain an understanding of the word* by-product. *A more difficult concept would be by-products made from metallic alloys [e.g., a bronze statue].)*

Assign groups of three students to research background information on metallic elements such as aluminum, nickel, silver, gold, mercury, copper, zinc, tin, lead, and iron and do a presentation on them. To help lead discussions in Activity 3, one group should research copper and another group should research aluminum. Specific roles that should be matched with student interests are:

- Lead computer researcher: a student who excels at using technology to research a topic. All group members should assist.
- Lead writer/compiler/media developer: a student who is good at synthesizing information and putting it in a visually appealing format. All group members should assist.
- Lead presenter: a student who tends to be gregarious, outgoing, and extroverted in nature. All group members should assist.

Some of the information students should investigate and questions they should answer are:

1. What is the chemical symbol for the metallic element?
2. What are chemical and physical properties of your assigned metallic element? (e.g., melting point, state at room temperature, density, etc.).
3. What is the current price of the element on the commodities market (see Resources)? *Students have noticed that these prices fluctuate and sometimes are priced based on unusual units of measurement (e.g., Troy ounces).*
4. What are three common uses for the metallic element by itself? *This is a tricky question in that most metal products are not a 100% pure element. Most students determine that a metallic element is mixed to form an alloy of some type.*
5. What are three common uses for the metals when combined with other elements to form compounds? *The word* compound *may be new for some students. Provide a few examples (e.g., all-metal compounds such as bronze, which is made of tin and copper, and carbon steel, which is made of iron and carbon, or other types of compounds, such as silver nitrate, which are made of the metal silver and a nonmetal nitrate (combination of nitrogen/oxygen), etc.*
6. Where is the metallic element mined? Which state or country is the greatest producer of the metallic element?
7. Provide a timeline-based history of the metallic element. There should be a minimum of four important moments in history regarding the metallic element.
8. Develop a presentation using presentational software (e.g., PowerPoint) or posters. As part of the presentation, develop answers to questions 1–7. By the end of the first activity, each group should have a visual product to make a class presentation. To meet requirements for this assignment, see Figure 1 at *www.nsta.org/middleschool/connections.aspx.*

Activity 2: To recycle or not to recycle

Recycling metals is an environmental success story. Aluminum, iron, copper, silver, and gold are some of the commonly recycled metals throughout the United States. This activity involves student groups choosing a metallic product for analysis. Their end objective is to determine the recycling potential of their metallic product.

Prior to beginning this activity, consider each student's mathematical skill level and place students in groups by heterogeneous ability. Hence, groups should be rearranged and increased by one from the first ac-

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Standards
MS-PS1: Matter and Its Interactions *http://nextgenscience.org/msps1-matter-interactions*

Performance Expectations
The materials, lessons, and activities outlined in this article are just one step toward reaching the performance expectation listed below.
MS-PS1-2. Analyze and interpret data on properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

Dimension	Name and *NGSS* code	Matching student task or question taken directly from the activity
Science and Engineering Practices	Analyzing and Interpreting Data Engaging in Argument from Evidence	• Students research and analyze data on a variety of metallic elements to determine if they are worth recyling. • "Would your product be something worth recycling? Tell us why or why not. Give evidence from your research and cost analysis to support your answer."
Disciplinary Core Ideas	PS1.A. Structure and Properties of Matter • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.	• "What are the chemical and physical properties of your assigned metallic element? (e.g., melting point, state at room temperature, density, etc.)." • "What are three common uses for the metals when combined with other elements to form compounds?"
Crosscutting Concepts	Cause and Efffect	• "What are some possible reasons for the difference between commodity market and product sales price?"

Connecting to the *Common Core State Standards, Mathematics* (NGAC and CCSSO 2010)

Ratios and Proportional Relationships
CCSS.Math.Content.6.RPA.1
CCSS.Math.Content.6.RPA.2
CCSS.Math.Content.6.RPA.3

The Number System
CCSS.Math.Content.6.NSA.1

tivity to ensure a student with high math skill levels is in each group. Working in groups of four, students select three possible metal products for cost analysis and possible recycling. Because some groups may have researched an expensive metal such as gold in Activity 1, it is not a requirement that Activity 2 groups analyze metal products that are made from the metallic element they researched in Activity 1.

Based on past experience, students should choose smaller metal products (free of nonmetallic components) to make mass, volume, and density calculations.

Based on past experience, students should choose smaller metal products (free of nonmetallic components) to make mass, volume, and density calculations. Examples of metal products include nails, screws, washers, nuts, tacks, paper clips, brads, coins, aluminum cans, small wrenches, round-edge metal scissors, pieces of copper wire, lead weights, aluminum bats, etc. For safety reasons, the teacher may want to bring in the metal products for analysis. If groups are allowed to bring items from home, both parental and teacher permission for a specific object should be required before anything is brought to school. In the assignment, students are asked to answer specific questions to determine the true value of the metals before making a decision on whether they should recycle them. Assessment for Activity 2 will depend on students' ability to answer questions regarding the metal object they selected to test/observe.

Figure 2 shows observations from students who chose paper clips for recycling, followed by cost-analysis questions and their answers (summarized in italics). There is a plethora of metal products that students can investigate with regard to possible recycling. The questions in Figure 2 can be answered using other metal products with a little research (see the online version of this article). Furthermore, without doing extensive chemical analysis, students can gather information through internet searches and physical observations that include using a magnet to separate and determine metal types.

As a conclusion and discussion point for Activity 2, we have each group present their findings with an emphasis on whether the metal object is worth recycling and why. While most agree the object should be recycled, most recommend reusing rather than returning for scrap metal.

FIGURE 2 Recycling a metal

1. What are the primary metals in your product? Usually the internet offers information on both how an object is made and the object's composition. Using the internet, groups were able to determine the metal composition in a paper clip.
   Galvanized steel: primarily iron with some zinc and manganese

2. How much would it cost to buy your product?
   Ten regular-size paper clip boxes (100 clips per box) $7.50, 0.75 cents/paper clip

3. What is the mass of your product? Due to the accuracy of our balance, I tell students to first mass a large quantity (if they are investigating a small metal object) to improve the accuracy of measurement per unit (i.e., one paper clip).
   100 regular-sized paper clips have a mass of 46 g. Hence, one paper clip is 0.46 grams.

4. What is the value of the primary metal in your product based on current commodity market prices?
   Iron ore current market price is $69.34/ton
   Iron ore current market price in metric kilograms is (2000 pounds × 454 grams/pound × 1kg/1000 grams= 908 Kg)= $69.34/908 Kg= $0.08/Kg

Activity 3: Recycling copper

After reading the Background Information (available with this article's online supplements at *www.nsta.org/middleschool/connections.aspx*), have the copper and aluminum groups from Activity 1 help lead the discussion.

Questions that can be investigated and discussed include:

1. What country no longer has a copper cent? Why?
2. Is copper worth recycling? (The value of copper and the demand for it should be a part of the discussion.)
3. What are some sources for copper recycling?
4. Why is copper so valuable?

FIGURE 2 Recycling a metal (continued)

5. What is the difference in cost of product and the primary metal's actual value? (These calculations required some teacher assistance, though each student in the group understood the calculations.)
We assumed the paper clips we used were 95% iron because they are only plated to prevent rust. We know they are made of iron because a magnet could pick up quite a few. We couldn't find the exact percentage of iron, though we did find that they were just electroplated with zinc and manganese to respectively prevent rust and make them stronger.

   0.95 iron/paper clip x 0.46 g/paper clip = 0.44 g iron in one paper clip

   Price of one paper clip = 0.75 cents

   Commodities market cost of iron in one paper clip: 8 cents/1000 g × 0.44 g of iron = 0.0035 cents

   Profit margin per paper clip: 0.75 cents – 0.0035 cents = 0.75 cents

6. What are some possible reasons for the difference between commodity market and product sales price? Students can find answers to some of these questions through internet investigations. However, some of the answers are generated and speculated upon through group discussions. Thus, both fact and opinion are derived through the answering of this question.
Metal in large bulk costs less
Cost to galvanize
Manufacturing process to make the wire and bend the wire
Cost of packaging
Cost of marketing
Salaries
Greed

7. Would your product be something worth recycling? Tell us why or why not your object is worth recycling. Give evidence from your research and cost analysis to support your answer.
Our product gets recycled all the time. However, taking it to a scrap metal place is not really cost effective based on our calculations. Unless the paper clip somehow gets bent out of shape we see no reason to buy more. We recommend that paper clips get reused instead of new ones being purchased. We believe there are enough loose paper clips in the world that there really is no reason to manufacture or buy more.

8. How many paper clips will it take to get a return of $100 if recycled at a scrap metal yard? (Students can call a local scrap company or there are multiple internet listings of prices that can be found at websites that give price quotes).
One listing students used to make their calculations was that steel wire on the high side ran about $40/ton. For a more accurate and current price quote, students should call a local scrap metal recycling company in their area.

   Recycling steel wire (2000 pounds × 454 g/pound × 1 kg/1000 g = 908 Kg) = $40/908 Kg = 0.045 cents/Kg

   Number of paper clips = (1 paper clip/.46 g)(1000 g/1 Kg)(1Kg/0.045 cents)($100)

   Number of paper clips = 4,830,918

   As we said in question 7, you would be better off reusing than trying to recycle that many paper clips.

9. What is the density of a paper clip?
To improve accuracy, students are encouraged to mass 10 or more paper clips, followed by finding the water displacement of 10 or more paper clips, to determine density.
Mass of 10 paper clips = 4 grams
Water displacement = 1 ml

   Density of paper clip = 4 g/ml

10. How does your paper clip's density compare to the "book value" for the density of iron (7.86 g/ml)? Explain.

    Because a paper clip is not pure iron, the densities differ from the "book value." Also, the accuracy of density measurement is limited by the measuring instruments we had available. Our teacher pointed out that being able to measure up to two decimal places meant that the book value iron density used some more precise instruments.

5. What advantages are there to making your barges out of aluminum instead of iron or lead?
6. Can a ship be made of iron?
7. What are some uses for copper and aluminum?
8. Where in the world are copper and aluminum mined?
9. How much copper and aluminum get recycled in a year?

The lesson focus is on designing an aluminum barge to recycle "copper" pennies (see the Activity Worksheet). This activity can be expanded using other metal items such as washers, steel paper clips, and zinc chips. This activity involves tubs of water. Students will need to be cautious around the water-tub station. Water might spill on the floor, so students need to walk, not run, and be aware of the possibility of standing water on the floor. Immediately wipe up any spills. Students should wear indirectly vented chemical splash goggles during this activity.

This particular activity has some classroom management challenges. Specific jobs to help facilitate and address differentiated instruction are identified in Figure 3. See Figure 4 for interesting facts about Lincoln pennies.

Assessments for Activity 3

Rubric assessments for Activity 3 are available online. A rubric for the main activity and a rubric for the extension component are provided (see Figures 6 and 7 at *www.nsta.org/middleschool/connections.aspx*).

Postactivity overview

The activities can be completed in four class days, at minimum; with shorter class periods (e.g., 50 minutes), it may take six or more days to complete. Teachers can differentiate instruction for all the

FIGURE 3 Classroom management and differentiated instruction

Students will be assigned a certain job within their cooperative groups (four people in a group). It is suggested to first assign jobs to students based on knowledge of student performance (particularly in math) and interests.

Jobs

Copper recycler/tester

- Description: to count the number of pennies that are put into a barge
- Tests the barge by putting it in the water tub, puts pennies in a barge, and counts number of pennies going in a barge

Barge constructer

- Constructs the barge based on input from group members

Designer

- Draws design of a barge
- Acts as project manager
- Keeps group members focused and on task

Recorder

- Records information
- Calculates the percentage of copper in pennies and takes lead in additional math computations and questions
- Is responsible for the final write-up

All group members are expected to contribute answering questions and completing the writeup.

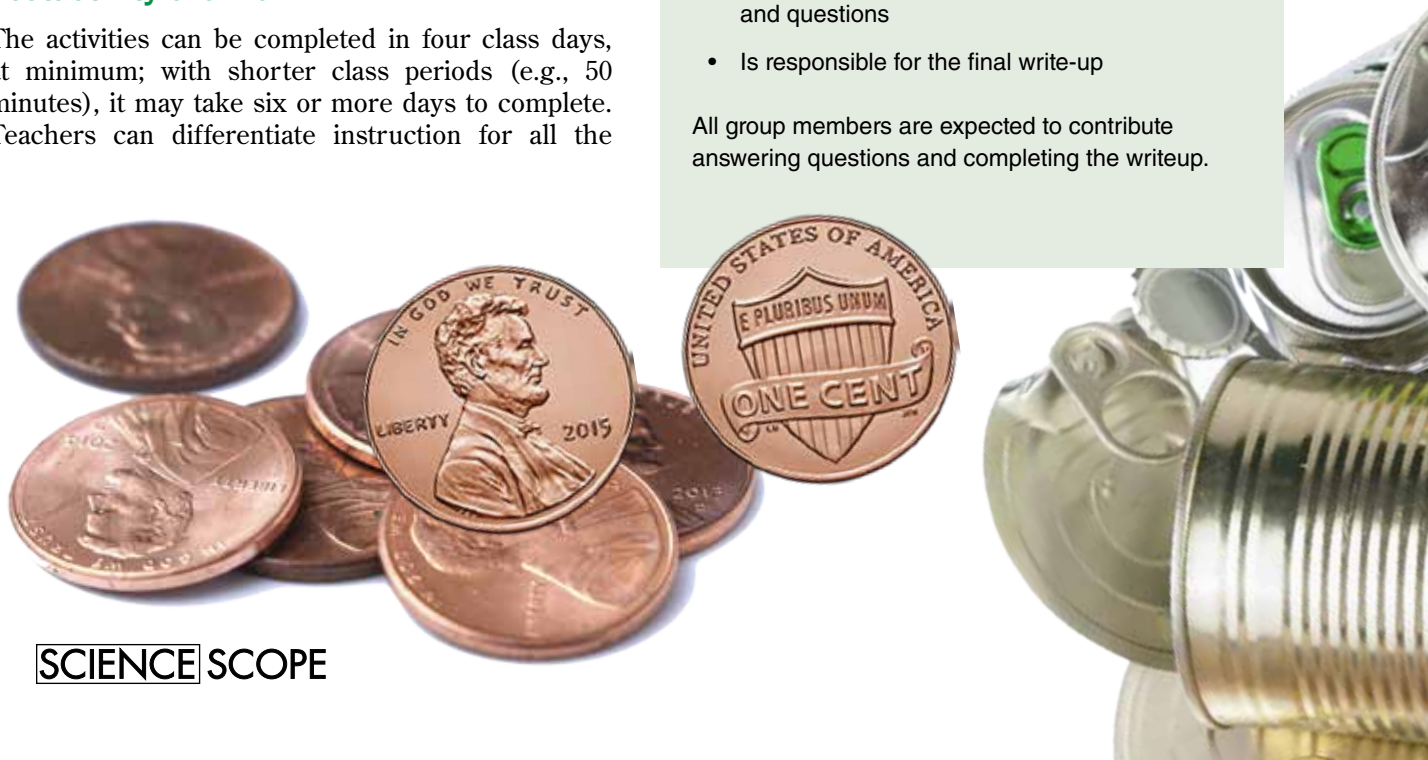

FIGURE 4 Lincoln penny facts

1. Lincoln pennies prior to 1959 were called “wheat pennies” due to the reverse image of wheat stalks.
2. Lincoln pennies prior to 2009 displayed the Lincoln Memorial. Using a magnifying lens and a penny that has minimal wear, you can see the statue of Abraham Lincoln seated inside the memorial.
3. Lincoln pennies celebrated Lincoln’s bicentennial birthday with four different 2009 reverse images: birth and early childhood in Kentucky, formative years in Indiana, professional life in Illinois, and presidency in Washington, DC.
4. From 2010 to today, the reverse side of the Lincoln penny has the Union Shield.
5. A rare 1943 copper penny is valued between $82,500 and $100,000. Technically copper pennies were not struck in 1943, though a few were produced by mistake.
6. A rare 1944 steel penny is valued at around $100,000 in good condition. Technically, steel pennies ended production in 1943, though a few were produced by mistake.
7. The 1914 D wheat penny in good condition is valued at around $3,550 and the 1909 S Vdb around $2,250.
8. The 1955 penny, if double-stamped (there are two 1955s on the penny) and in excellent condition, is valued at around $1,200.
9. It is roughly estimated that there are over 200 billion pennies in circulation, according to the U.S. Mint.
10. Due to copper differences, the pre-1982 uncirculated pennies (excellent condition) have a mass of 3.11 g, while the post-1981 uncirculated pennies (excellent condition) have a mass of 2.50 g.

www.usmint.gov/about_the_mint/fun_facts/?action=fun_facts2
http://coins.thefuntimesguide.com/2008/07/rare_wheat_pennies.php
http://coins.about.com/od/famousrarecoinprofiles/a/lincoln_cents.htm
www.treasury.gov/about/education/Pages/lincoln-cent.aspx

activities by placing students in groups that are heterogeneous by skill levels in mathematics (Activities 2 and 3), reading/writing (Activities 1–3), and research technology (Activities 1–3). Furthermore, student interests and learning styles are addressed in the activities based on group job assignments.

These activities address both the *Next Generation Science Standards* and the *Common Core State Standards* in Mathematics. The lowest chosen grade level for standards alignment was sixth grade. Extension to standards in a higher grade (i.e., grades 7–8) is possible with Activities 2 and 3. The nature of Activities 2 and 3 requires that students understand multiple grade-level mathematical concepts. These concepts are described in detail within the activities.

Conclusion

These activities provide relevance for the learning of a variety of scientific knowledge (e.g., historical aspects of metallic elements) and scientific concepts (e.g., density and buoyancy). Furthermore, ideas related to environmental science (e.g., recycling), engineering (e.g., design and decision-making processes), and mathematics (e.g., percentages, ratios, proportions, and problem solving) are emphasized throughout the activities. With minimal cost, these activities effectively make science, engineering, and mathematics relevant subjects to the student.

Finally, these activities can be integrated with various other subjects. In the social studies classroom, students can learn about the importance of barge transportation and the economic side of metal sales. In the language arts classroom, students can write a letter to a recycling company asking questions about the processes behind copper or other metals reclamation. The arts education teacher can have students come up with a marketing advertisement (flyer or a billboard) that displays their recycling company or advertises a metal they are recycling. ■

Acknowledgment

The author thanks Erin Mattox for her assistance in the editing of this manuscript.

References

National Governors Association Center for Best Practices and Council of Chief State School Officers (NGAC and CCSSO). 2010. *Common core state standards*. Washington, DC: NGAC and CCSSO.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Resources

Current commodity market prices of most metals—*www.infomine.com/investment/metal-prices*

The history of the Lincoln cent—*http://coins.about.com/od/famousrarecoinprofiles/a/lincoln_cents.htm*

Mining, markets, and investment—*www.infomine.com/investment/metal-prices*

Scrap monster—*www.scrapmonster.com*

U.S. Treasury: History of the Lincoln cent—*www.treasury.gov/about/education/Pages/lincoln-cent.aspx*

William Sumrall *(sumrall@olemiss.edu)* is a professor in the Department of Teacher Education at the University of Mississippi in University, Mississippi.