Can You Copperplate?

Provided by TryEngineering - www.tryengineering.org

Lesson Focus
Lesson explores chemical engineering and explores how the processes of chemical plating and electroplating have impacted many industries. Students work in teams to copper plate a range of items using everyday materials. They develop a hypothesis about which materials and surface preparations will result in the best copper plate, present their plans to the class, test their process, evaluate their results and those of classmates, and share observations with their class.

Lesson Synopsis
The "Can You Copperplate?" lesson explores how engineers work to solve the challenges of a society, such as adjusting the surface of a metal to achieve a particular goal or outcome. Students work in teams to devise two systems for plating metal objects with copper. The teams develop their strategies, present them to the class, conduct a test to see which strategy worked best, reflect on the challenge, and present their findings to their class.

Age Levels
12-18.

Objectives

- Learn about engineering design and redesign.
- Learn about chemical engineering.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes
As a result of this activity, students should develop an understanding of:

- chemical engineering
- chemical plating and electroplating
- safety and society
- teamwork

Lesson Activities
Students explore how engineers have solved societal problems such as developing and improving metal parts by adding a layer of another material to the surface. Students work in teams to develop a chemical system to add a layer of copper to another metal product. They test and evaluate their own results and the results of other teams, and share their reflections with the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Euro Copper Content (www.copperinfo.co.uk/coins/)
- Metal Finishing Magazine (www.metalfinishing.com)
- NASA Corrosion Technology Laboratory (http://corrosion.ksc.nasa.gov)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

Recommended Reading

- Modern Electro Plating (ISBN: 978-1149471944)
- The Polishing and Plating of Metals (ISBN: 978-1246867176)
- Electro-deposition of Metals (ISBN: 978-1176590250)

Optional Writing Activity

- Write an essay or a paragraph about why nails used in construction are galvanized.

Optional Extension Activity

- Have older students try electroplating the copper in a lab setting.

Safety Precautions

- Have students wear gloves when removing the materials from solution, or when disposing of solution.
- This activity should be done in a well-ventilated area as the solution can give off an odor after the plating process.

Can You Copperplate?

For Teachers:
Teacher Resources

◆ Lesson Goal

The "Can You Copperplate?" lesson explores how engineers work to solve the challenges of a society, such as adjusting the surface of a metal to achieve a particular goal or outcome. Students work in teams to devise two systems for plating metal objects with copper. The develop their strategies, present these to the class, conduct a test to see which strategy worked best, reflect on the challenge, and present their findings to their class.

◆ Lesson Objectives

- Learn about engineering design and redesign.
- Learn about chemical engineering.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

◆ Materials

- Student Resource Sheets
- Student Worksheets
- Classroom Materials (water source, bucket or sink area -- hundreds of dirty pennies, euros or other coins or materials with a high copper surface content)
- Student Team Materials: glass jar (jelly or canning jars work well), 25 pennies, euros, or any coin with copper coating, other coins, iron nail or screw, aluminum bolts, salt, white/clear vinegar, lemon juice, baking soda, scouring pad, water, metal paperclips, other non-valuable metal items for students to experiment with.

◆ Procedure

1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, consider showing students several different screws or bolts with different finishes and ask them why different finishes are manufactured.
3. Teams of 3-4 students will consider their challenge, and develop two different plans for plating one of their items. They may use different solutions, materials, timings, etc…but each must incorporate a pile of older pennies, euros, or other coins or materials with high external copper content - and use a glass container. (see www.copperinfo.co.uk/coins for EUROs)
4. Teams then present their two plans to the class.
5. Students may revise their plan, then conduct their two tests, and observe their results and those of other teams.
6. Teams reflect on the challenge, and present their experiences to the class.

◆ Time Needed

One to two 45 minute sessions.

◆ Notes and Cautions

1. Do not use valuable coins in this lesson as the finish will be altered and may impact collectible coin value.
2. Students should not drink the lemon juice or vinegar solution either before or after coins have been submerged; wearing gloves and goggles is recommended.

For Teachers:
Teacher Resources

◆ **Teacher Tips**

Several methods will be successful at removing a layer of copper from the pennies or other copper surfaced items and transferring the copper to another metal item. See a suggested solution below --- consider if you want to provide these methods to the teams or whether you would like teams to come up with a solution on their own.

Be sure to review and supervise ALL solutions developed for safety.

Solution:

Put 25 older/dirty pennies (or other coins or materials with high external copper content) into a glass jar with 1/2 cup (125 ml) of white vinegar and 1/4 teaspoon (1ml) of salt. Let sit for 5 minutes, then add an iron nail, screw, or other item (Not galvanized). Be sure to clear the iron item first -- you can use a sponge with baking soda on it, or scrub with a steel wool pad so the surface is exposed. Let pennies and iron item soak for 15 minutes. Pennies should be shiny and nail should have thin coating of copper.

Notes:

- You can substitute lemon or orange juice for the white vinegar. Students will be able to see what is happening better with the vinegar or lemon juice.
- Dispose of resulting liquid in a sink (can be a smelly mixture).
- If the pennies are not rinsed in water after the experiment, they will turn blue-green after a few days.

Why does this work?

Copper oxide will dissolve when exposed to the acid solution resulting from the mixture of vinegar and salt

After the experiment, unrinsed pennies will turn green in a few days because when exposed to the acid and left to air dry, the exposed copper atoms will react with oxygen and remaining salt to make blue-green malachite.

The iron materials are coated with copper because when the pennies are in the solution some of the surface copper will dissolve. But when copper atoms leave the penny, they leave some of their electrons behind….really positively charged copper ions (copper atoms that are missing two electrons). Likewise, some of the metal in the iron dissolves and there are positively charged iron ions floating in solution with the positively charged copper ions. When the iron ions leave the nail/screw, the item becomes negatively chared and so attracts the positively charged ions in solution. Copper ions are more strongly attracted to the iron item than the iron atoms, so they coat the item with a thin coating of copper.

Student Resource: Chemical Engineering

◆ What do Chemical Engineers do?

Chemical engineers apply the principles of chemistry to solve problems involving the production or use of chemicals and other products. They design equipment and processes for large-scale chemical manufacturing, plan and test methods of manufacturing products and treating byproducts, and supervise production.

◆ Where do Chemical Engineers Work?

Chemical engineers work in manufacturing, pharmaceuticals, healthcare, design and construction, pulp and paper, petrochemicals, food processing, specialty chemicals, polymers, biotechnology, and environmental health and safety industries, among others. Within these industries, chemical engineers rely on their knowledge of mathematics and science, particularly chemistry, to overcome technical problems safely and economically. And, of course, they draw upon and apply their engineering knowledge to solve any technical challenges they encounter.

Chemical engineers also work in a variety of manufacturing industries other than chemical manufacturing, such as those producing energy, electronics, food, clothing, and paper. In addition, they work in healthcare, biotechnology, and business services. Chemical engineers apply principles of physics, mathematics, and mechanical and electrical engineering, as well as chemistry. Some may specialize in a particular chemical process, such as oxidation or polymerization. Others specialize in a particular field, such as nanomaterials, or in the development of specific products. They must be aware of all aspects of chemical manufacturing and how the manufacturing process affects the environment and the safety of workers and consumers.

Chemical engineers typically do the following:

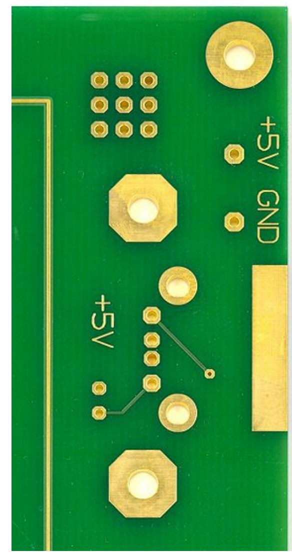
- Develop safety procedures for those working with potentially dangerous chemicals
- Troubleshoot problems with manufacturing processes
- Evaluate equipment and processes to ensure compliance with safety and environmental regulations
- Conduct research to develop new and improved manufacturing processes
- Design and plan the layout of equipment
- Do tests and monitor performance of processes throughout production
- Estimate production costs for management
- Develop processes to separate components of liquids or gases or to generate electrical currents using controlled chemical processes

(Note: Some resources in this section provided by the Sloan Career Cornerstone Center - www.careercornerstone.org - and the U.S. Bureau of Labor Statistics.)

Student Resource: Plating Processes

◆ Metal Plating

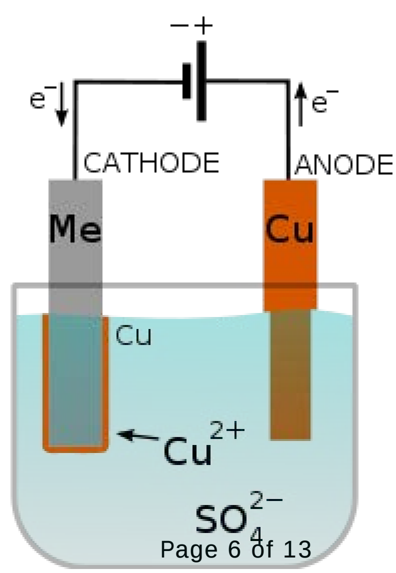
Plating of metals has been done via many processes since ancient times. Gold plating is a method of depositing a thin layer of gold onto the surface of another metal, most often copper or silver (to make silver-gilt), by chemical or electrochemical plating.



Electroplating has many uses….it can make a material more resistant to damage or abrasion….it can make a material look nicer….to harden a surface…to reduce friction….to improve paint adhesion, to alter conductivity, for radiation shielding, and for other purposes. It is also used to build up the thickness of undersized parts. It is widely used in industry for coating metal objects with a thin layer of a different metal. The layer of metal deposited has some desired property, which the metal of the object lacks. For example, chromium plating is done on many objects such as car parts, bath taps, kitchen gas burners, wheel rims and many others. Gold is often plated onto silver or a less expensive metal to reduce the cost of jewelry. Gold plating is often used in electronics, to provide a corrosion-resistant electrically conductive layer on copper, typically in electrical connectors and printed circuit boards. The surface of nails used in construction are sometimes galvanized which adds a layer of zink.

◆ What is Electroplating?

Electroplating is a process in which metal ions in a solution are moved by an electric field to coat an electrode. The process uses electrical current to coat a conductive object with a thin layer of the material, such as a metal. The process used in electroplating is called electrodeposition. In one technique, the anode is made of the metal to be plated on the part. Both components are immersed in a solution called an electrolyte containing one or more dissolved metal salts as well as other ions that permit the flow of electricity. A power supply supplies a direct current to the anode, oxidizing the metal atoms that comprise it and allowing them to dissolve in the solution.



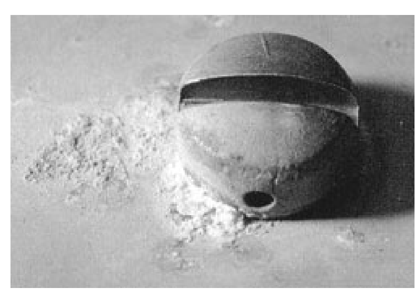
At the cathode, the dissolved metal ions in the electrolyte solution are reduced at the interface between the solution and the cathode, such that they "plate out" onto the cathode. The rate at which the anode is dissolved is equal to the rate at which the cathode is plated, vis-a-vis the current flowing through the circuit. In this manner, the ions in the electrolyte bath are continuously replenished by the anode.
In the example to the right, in an acid solution, copper is oxidized at the anode to Cu2+ by losing two electrons. The Cu2+ associates with the anion SO42- in the solution to form copper sulfate.

Student Resource:
Galvanic Corrosion

◆ Galvanic Corrosion

Galvanic corrosion is an electrochemical action of two dissimilar metals in the presence of an electrolyte and an electron conductive path. It occurs when dissimilar metals are in contact. When this happens, you'll see a buildup of corrosion at the joint between the dissimilar metals.

The galvanic series (or electropotential series) is a scale that shows the nobility of metals and semi-metals. The farther apart the metals are in the galvanic series, the greater the galvanic corrosion effect or rate will be. Metals or alloys at the upper end are noble while those at the lower end are active. The more active metal is the anode or the one that will corrode. Control of galvanic corrosion is achieved by using metals closer to each other in the galvanic series or by electrically isolating metals from each other. Galvanic reaction is the principle upon which batteries are based.



NASA's Corrosion Technology Laboratory conducts research on the effects of galvanic corrosion. The photo at the right shows the corrosion caused by a stainless steel screw causing galvanic corrosion of aluminum. Find out more at http://corrosion.ksc.nasa.gov.

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Student Worksheet:

◆ **Engineering Teamwork and Planning**

You are part of a team of engineers given the challenge of applying a copper surface to another metal. You can choose the metal item/items you want to plate and also the chemical solution and timing you think will work best. You will develop two different approaches and see which works best.

Step 1: Determine two methods for copper plating and identify your items. Note, you may wish to consider placing multiple items in one of the solutions…but be aware that any copper released from the pennies or other copper based coins you have will then be diluted between multiple metal items and so you may not see results. In the box below, describe your solution, method, timing, and the items you will copper plate.

Solution	Describe Solution (include quantity of each item you will include)	Describe items to be plated	Describe method (including timing, rinsing methods, etc.)	Anticipated Result
1				
2				

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Student Worksheet:

◆ Presentation and Testing

Step 2: Present your plan and anticipated outcome to the class. Consider the ideas of the other teams and adjust your plan if you like.

Step 3: Test your two methods and note your observations in the box below.

Solution	What Happened to the Solution?	What Happened to the Item you were trying to plate?	What happened to the pennies or copper surfaced items/coins?	Did this method work?
1				
2				

Student Worksheet:

◆ Reflection

Complete the reflection questions below:

1. Was your team able to copperplate a metal item? What factors do you think contributed to the success or failure of your method?

2. If you found you needed to make changes to your method after listening to the methods planned by other teams, describe why your team decided to make revisions.

3. Which method that another team adopted was the most successful? Why do you think this method worked so well?

4. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

5. Do you think that chemical engineers have to make many attempts to achieve a goal? What do you think it would be like to fail over and over before having success?

6. What industry or business do you think might want to use the method you developed?

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Properties of objects and materials

CONTENT STANDARD D: Earth and Space Science

As a result of their activities, all students should develop an understanding of

- ✦ Properties of earth materials

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understanding about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Types of resources
- ✦ Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Properties and changes of properties in matter

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in society

For Teachers: Alignment to Curriculum Frameworks (cont.)

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor
- ✦ History of science

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- ✦ Chemical Reactions
- ✦ Structure and properties of matter

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Natural resources
- ✦ Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor
- ✦ Historical perspectives

◆Next Generation Science Standards – Grades 2-5 (Ages 7-11)

Matter and its Interactions

- ✦ 2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

Engineering Design

Students who demonstrate understanding can:

- ✦ 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- ✦ 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- ✦ 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆Next Generation Science Standards - Grades 6-8 (Ages 11-14)

Matter and its Interactions

- MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.
- Standard 13: Students will develop abilities to assess the impact of products and systems.