Build a Recycling-Sorting Machine

Summary

GRADE RANGE

6th-8th

GROUP SIZE

2-3 students

ACTIVE TIME

2 hours

TOTAL TIME

2 hours

AREA OF SCIENCE

Physics

KEY CONCEPTS

Forces, magnetism, engineering design

CREDITS

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https://www.youtube.com/watch?v=Th6GQiSHfKk

Overview

In this lesson plan, your students will build their own recycling sorting machines that use various methods, like magnets or puffs of air, to separate shreds of paper from paper clips. This lesson is inspired by the real-world engineering challenge of separating various materials, like paper, plastic, and metals, that get combined in single-stream recycling programs.

Learning Objectives

- Understand that magnets exert forces even when they are not in contact with each other
- Understand the factors that affect the strength of magnetic forces
- Evaluate competing design solutions using the same criteria

NGSS Alignment

This lesson helps students prepare for these Next Generation Science Standards Performance Expectations:

• **MS-PS2-3**. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

• **MS-PS2-5**. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

• **MS-ETS1-2**. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

This lesson focuses on these aspects of NGSS Three Dimensional Learning:

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions. Apply scientific ideas or principles to design an object, tool, process or system. **Engaging in Argument from Evidence.** Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	**PS2.B: Types of Interactions.** Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, a magnet, or a ball, respectively). **ETS1.B: Developing Possible Solutions.** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.	**Influence of Science, Engineering, and Technology on Society and the Natural World.** The uses of technologies and limitations of their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

Materials

- Paper clips
- Paper
- Magnets
- Scissors
- Cardboard
- Tape
- Cups
- Optional: other construction/craft materials such as wooden craft sticks, glue, pipe cleaners, etc.

Background Information for Teachers

This section contains a quick review for teachers of the science and concepts covered in this lesson.

Single-stream recycling programs allow us to mix all of our recyclables—like paper, plastics, and metals—in a single container. These containers are collected by trucks and transported to Materials Recovery Facilities (MRFs). These facilities use a variety of machinery, combined with some manual sorting by humans, to separate all the different materials (Figure 1). For example, large magnets can pull ferrous metals (like tin cans) away from the rest of the waste. Puffs of air can blow lighter materials upward while heavier materials fall down. Sieves allow small objects to fall through the holes while larger objects keep going. Multiple videos listed in the Additional Background section show MRFs in action.

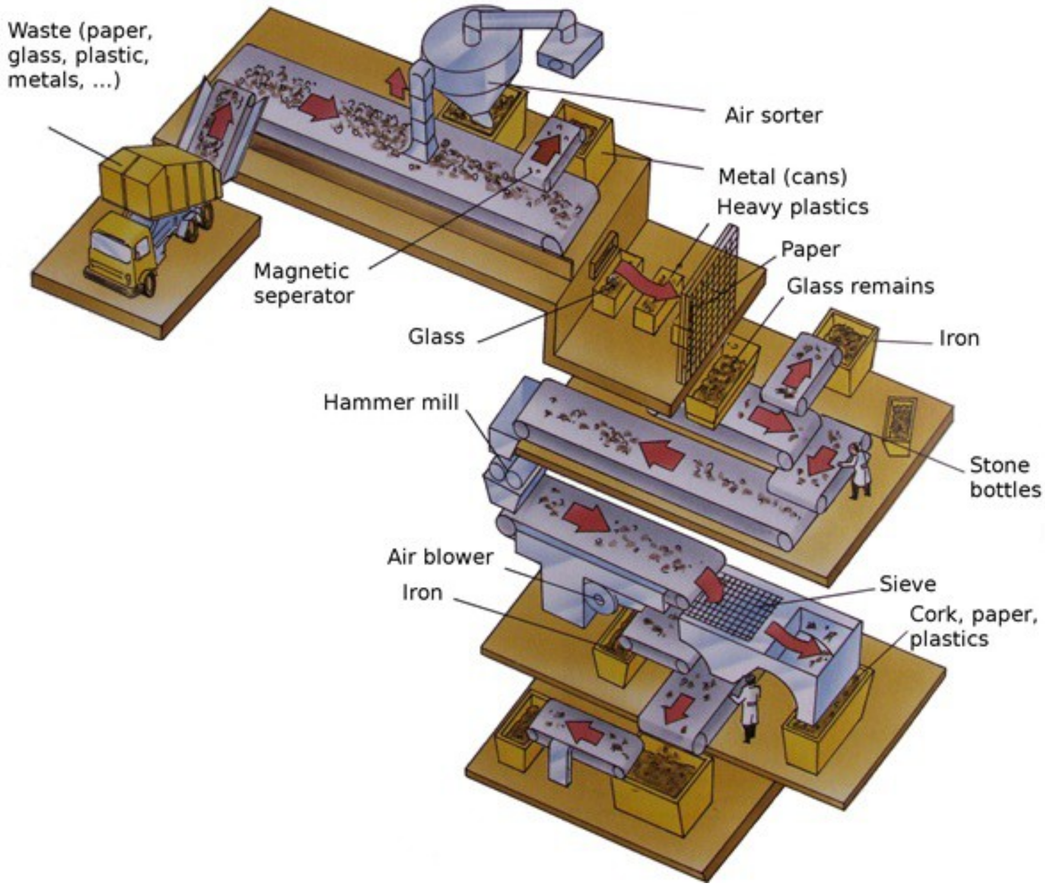

Figure 1. Diagram of a materials recovery facility.

In this lesson plan, students will build their own miniature materials recovery facility. They will focus on separating just two materials: paper clips and shreds of paper. Multiple methods—like magnets, puffs of air, or manual sorting (or a combination thereof)—can be used to do this. Students will experiment with different methods and build a machine to sort the two materials as quickly as possible.

This lesson can be used to teach students about magnetic forces and magnetic fields. For example, students will notice that the magnets exert forces on each other, and the paper clips, even when they are not in direct contact. They can explore what parameters have effects on these forces, such as the distance or orientation of a magnet relative to the paper clips. See the tutorial linked in the Additional Background section for more information about magnetism.

Finally, you can also use this lesson to spur conversation about the pros and cons of recycling, and ask students to do further research about recycling as a homework assignment or follow-up project. See the references in the Additional Background section to get started.

Additional Background Links

Articles about problems with recycling (note: this is a current topic, you may want to check the news for more recent articles or local articles about your community):

- With 'Single-Stream' Recycling, Convenience Comes at a Cost, NPR
- The World's Recycling Is in Chaos. Here's What Has to Happen, Wired

Videos showing how Materials Recovery Facilities work:

- The Big Sort: An Insider's Tour of a Recycling Plant, Science Friday
- How it Works: Single Stream Recycling, Waste Management

Other useful references for this project:

- Electricity, Magnetism, & Electromagnetism Tutorial, Science Buddies
- The Engineering Design Process, Science Buddies

Prep Work (15 minutes)

- Prepare shreds of paper approximately 1×1 cm. This can be done quickly if you fold the paper before cutting.
- Arrange separate cups of "recyclable" material for each group of students. For example, each group could be given a cup of 50 paper clips and 50 shreds of paper. Make sure the cups are well-mixed (e.g., not a pile of paper clips sitting on top of a pile of paper).

Engage (10 minutes)

1) Start the class with a discussion about recycling. If your community/school does not have single-stream recycling, you will have to introduce the concept to students. Make sure students understand that ultimately, in order for materials to be recycled (e.g. old plastic bottles turned into new plastic bottles, used paper turned into new paper, etc.) the materials must be sorted somehow.

2) Ask students how they think materials are sorted in communities with single-stream recycling programs. For example, is the sorting all done by people? Is it done by machines? How could a machine automatically separate two materials like metal and paper, or glass and plastic?

3) Show students a video about how a recycling plant works, such as this one (other options are listed in the Additional Background section):

https://www.youtube.com/watch?v=nUrBBBs7yzQ

4) Explain that today students will work in groups to build their own miniature recycling-sorting machines. They will focus on separating only two materials: paper clips and shreds of paper.

Explore (1 hour)

1) Show students the materials they have available to work with. First, ask students to individually write down at least one idea for how they could separate paper clips and paper shreds using these materials. Then ask students to share their ideas with the class.

2) Next, have each group explore different methods of separating a mixed pile of paper clips and paper shreds, and record their observations in their student worksheets. Students can think of their own ideas, but you can also prompt them to try the following:

a. How difficult is it to sort the paper clips and paper shreds by hand?

b. What happens if you blow gently on a pile of paper clips and paper shreds? What happens if you blow harder?

c. What happens if you slowly bring a magnet towards the pile? Do the magnets need to touch the paper clips to attract them, or can they do it from a distance? Is there a certain distance you must reach before paper clips are attracted to the magnet? How many paper clips can a single magnet pick up?

d. Can you think of any other ways to separate the two materials? If so, try them!

3) Now, agree on criteria for the project as a class (or set these criteria yourself in advance). You will need to standardize this so you can evaluate the performance of each machine using the same criteria. These criteria may vary slightly based on the materials and time you have available, but here is a set of example criteria:

a. Each group must start with a well-mixed cup of 50 paper clips and 50 paper shreds.

b. The cup must be poured into their sorting machine. The machine should sort the paper clips and paper shreds into two separate containers (e.g. cups or boxes).

c. The machine and its parts can be operated by hand, and students can blow into the machine to create puffs of air. However, no manual sorting (individually plucking out paper clips or shreds) is allowed.

d. The machine's performance will be scored using the following equation.

$$Total\ score\ = (\#\ of\ paper\ clips\ and\ paper\ shreds\ in\ the\ correct\ container\ ) \ - \\ (\#\ of\ paper\ clips\ or\ shreds\ that\ are\ in\ the\ wrong\ container,\ or\ stuck\ in/fell\ out\ of\ the\ machine\ etc.)$$

With this equation and 50 paper clips/shreds each to start, it is possible to get a maximum score of +100 and a worst-case scenario score of -100.

Alternatively, you could allow manual sorting, but rank performance based on the fastest time to sort all 100 paper clips/shreds. This will encourage students to devise automated methods to speed up the sorting, but they can still use manual picking to sort out any stragglers or stuck pieces.

4) Next, applying what they learned in step 2, and taking the agreed-upon criteria into account, students should use the engineering design process to design a recycling sorting machine to separate the paper clips and paper shreds.

a. Each student can draw their own idea for a sorting machine in their worksheet.

b. Students can then share ideas within their groups and agree on a single design to build. This design can be a combination of individual designs, or a completely new one inspired by other ideas.

c. Each group should build a prototype of their sorting machine. They may want to test individual parts of it as they build to make sure they are working as intended. Emphasize that the engineering design process is *iterative*. Things do not always work perfectly on the first try. It is OK if they need to revise or change their design. Even if their machine "works," they should think about how to make it better. Any changes should be logged in their worksheet.

d. Students should make data tables to record the performance of their design across multiple iterations. The format of the table will depend on the criteria you decided on; e.g. they could record the number of correctly/incorrectly sorted paper clips/shreds, or the total time required to complete sorting. Does their sorting performance get better across multiple iterations?

5) After completing construction and testing, each group should perform a final test. Compare results across the class using your agreed-upon criteria. Which machine performed the best?

Reflect (15 minutes)

1) Discuss the results of your design project as a class. Here are some questions you can use to prompt discussion:

? *Which machines or methods worked best for separating the two materials?*

? *Are there any common mistakes students made or problems that multiple groups ran into?*

? *Did high-performing machines have anything in common?*

? *Did any groups come up with a design that was completely unique and different from every other machine?*

2) Discuss the pros and cons of single-stream recycling. Do students think single-stream recycling is a good idea or a bad idea? For example, more people might be willing to participate in single-stream recycling programs because recycling is less effort if you can just toss everything in one container. However, this requires that the materials be sorted later. As they saw in this lesson, technology and machines can do some of that sorting automatically, but it isn't perfect. If people aren't careful with recycling (e.g. throwing in trash or plastic bags), the materials can become contaminated or clog sorting machines.

Assess

- Collect your students' worksheets and use them as an assessment of the activity.
- Ask each group to make a poster or do a short presentation to the rest of the class about their sorting machine.

Make Career Connections

Discussing or reading about these careers can help students make important connections between the in-class lesson and STEM job opportunities in the real world.

Industrial Engineer In Demand

Career Profile

Industrial engineers figure out how to make *processes* work better. What are the best ways to separate different materials? How can you do it faster, cheaper, or with less contamination? If you enjoyed figuring out these problems while building your sorting machine, you should learn more about industrial engineering! Read more

Sustainability Specialist In Demand

Career Profile

Do you care about recycling and taking care of the environment? Do you want to figure out the best ways for humans to reduce waste and our impact on the planet? For example, how can communities improve their recycling programs? If you enjoyed the recycling theme to this project, try reading more about a career as a sustainability specialist! Read more

Lesson Plan Variations

• Use electromagnets instead of permanent magnets. This will allow you to pick up and then drop the paper clips. See our Strength of an Electromagnet lesson plan for instructions on making electromagnets.

• Design a machine to sort objects of different sizes. For example, see this marble-sorting machine project.

• Analyze the recycling bin in your own classroom, or ask students to do it at home. Can they determine the level of "contamination" (objects that aren't supposed to be mixed together or put in the recycling)?

• Have students do research about the current state of recycling in their local community or nationally/globally. The market for recycled materials is complex (e.g. in the late 2010's, China stopped buying many raw recyclable materials from the U.S., in part due to contamination from people not following recycling guidelines). See the Additional Background section for some references.