LESSON 1 Design Like an Eco-Engineer

OBJECTIVE

Students deepen their understanding of the engineering design process using a real-world case study, and apply the process in an eco-engineering challenge.

MATERIALS

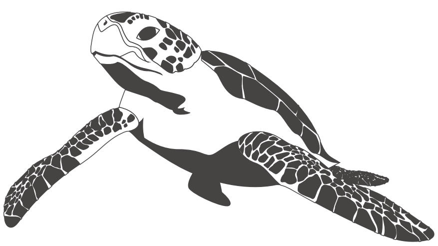
"Tackling the Plastic Disaster" reading passage, internet access, paper, tape, scissors, other modeling materials found readily in the classroom

TIME

75 minutes

CONTEST PREP

Review the contest entry form before completing this lesson; students will use the engineering design process to develop a manufacturing solution to a real-world problem.



CLASS DISCUSSION

Write or project the steps of the engineering design process on the board. Ask students how they think the steps are related. Discuss some of the points below. If students don't bring it up, tell them these are stages of the engineering design process. Explain that this process isn't always orderly. In practice, innovators may jump back and forth between steps or visit steps out of order. If you wish, show and discuss these videos about the process from NASA: bit.ly/1LeJa5P and go.nasa.gov/2PnkzFv.

ENGINEERING DESIGN PROCESS STEPS
Define the problem. What is inside and outside the scope of the problem?
Collect research. What is already known? What remains unknown? Use empathy: Who or what does the problem affect?
Specify requirements for your solution. What will a successful solution accomplish and not accomplish?
Brainstorm, evaluate, and choose a solution. Think of ideas. Compare and assess them. Decide which ideas you'd like to test further.
Develop and prototype a solution. Create a sample or test model.
Test your solution. Simulate realistic conditions. Does the prototype meet your requirements?
Communicate your results. Share your learnings. Solicit peer feedback. Gather funding.
Revisit any part of the process. Respond to failure. Do more research, iterate your prototype, brainstorm new ideas, or specify new requirements.

CASE STUDY

Distribute "Tackling the Plastic Disaster." Ask students to look for the steps of the engineering design process as they read. Students should use context and inference (or do research) to sketch diagrams and answer the questions at the end of the article. Have them share a few of their answers with the class.

ACTIVITY

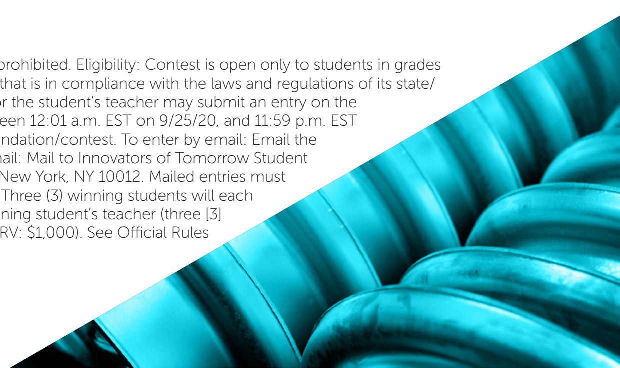
Ask students to work in pairs or small groups to apply the engineering design process to one of the eco problem statements below. Challenge them to use as many stages of the process as they can in the allotted time. Have students share their work with the class.

PROBLEM STATEMENTS

- Transportation (cars, trucking, air travel) continues to be one of the most significant contributors of pollution.
- Population growth creates an increase in home-energy consumption.
- The manufacture of single-use materials (packaging, plastic bags, straws) is detrimental to the environment.
- The food supply chain is a significant draw on our water sources, aquatic life, and more.

CONTEST | $1,000 CLASSROOM GRANTS

Use these lessons to prepare students to enter the Innovators of Tomorrow Contest. Students will develop an invention that uses advanced manufacturing to solve a problem. Three winning students will each receive a tablet, and their teachers will receive $1,000 for the classroom. Get details at **scholastic.com/arconicfoundation/contest**.



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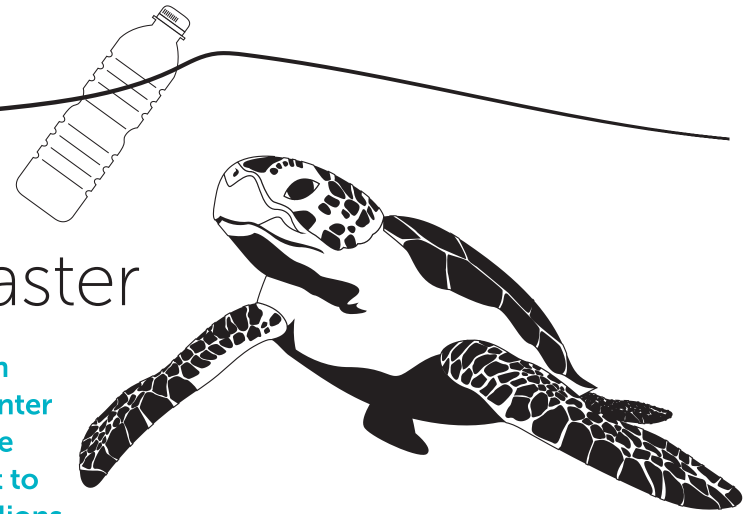


CASE STUDY

Tackling the Plastic Disaster

Meet Boyan Slat of the Netherlands. As a teenager, Boyan went scuba diving in Greece and was surprised to encounter more floating garbage than fish! After learning that entire animal species are threatened by the problem, he set out to clean up the huge patches of plastic that float across millions of square miles of our oceans.

Boyan devoted himself to learning more about the plastic littering the oceans. He read that the patches of floating plastic were so large that experts believed they could never be cleaned. Undaunted, Boyan asked himself: "Why can't we clean this up?" He dedicated a high school science project to understanding the problem, researching why a cleanup was considered impossible. Boyan discovered that the conventional idea for ocean cleanup—an **active system** involving a boat dragging a net that collects plastic and brings it back to shore—was so costly and slow-working that it could never make an impact on the problem.

Soon, he began conducting his own field research, using a boat to tow a manta trawl (a net system that resembles a manta ray) that gathered samples of the plastic floating on the water's surface. Then he expanded his field research, designing a **multilevel trawl** to figure out just how deep the problem went. During collection, Boyan's multi-level trawl snapped from the tremendous forces exerted on it. With his research cut short, Boyan learned that he'd need to come up with another approach.

After a year of researching and experimenting, Boyan came up with the idea for a **passive system:** a V-shaped boom (a boom is a floating barrier) that skims plastic with the help of ocean waves and currents. One small problem: The boom requires an anchor or it will float away, but you can't anchor things to the ocean floor. It's far too deep. Boyan kept researching solutions before landing on the idea for a system of drifting "anchors" 600 meters below the ocean's surface.

At sea during testing, parts of the prototype came loose from the mooring. Boyan and his team made adjustments to both the design and materials, switching from a soft, inflatable boom to a rigid boom made of pipe, solving for the mooring as they went. Boyan stresses the importance of testing on a small scale and making **iterative improvements** as you go. He says, "We test not to prove ourselves right, but to find things that don't work."

Boyan, now 26, and his nonprofit, The Ocean Cleanup, have raised millions in funding from the public and investors. The group launched their first cleanup system in the Great Pacific Garbage Patch in 2018. Using the lessons they learned, Boyan and his team continue to make design modifications and test improvements to the system. Track their progress at bit.ly/3fWLVyg.

DIVE IN

Write your answers on a separate sheet of paper.

1 EXPLAIN THESE TERMS from context using sketches and/or rough notes: multilevel trawl, active system, passive system, iterative improvements.

2 FIND EXAMPLES of stages of the engineering design process in the case study.

3 LIST THREE EXAMPLES of failure from the article. How is failing important to the engineering design Process?

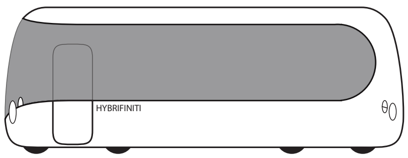
LESSON 2 Engineering Innovative Materials

OBJECTIVE
Students research emerging technologies in materials science and manufacturing processes, and apply their knowledge to make decisions.

MATERIALS
"Drive Progress" worksheet, internet access, ideally laptops for students or small groups

TIME
75 minutes

CONTEST PREP
This lesson familiarizes students with advanced materials and researching advanced manufacturing. They'll apply this knowledge in their contest entries.



CLASS DISCUSSION
1. Show a short video of a spider spinning a web (there are many readily available online, such as bit.ly/2kenkxL). Explain to your class that Materials Science Engineers are particularly fascinated by the work of spiders. Challenge your students to identify the connections between a spider spinning a web and human activity.
2. Explain that spiders and humans are builders. The similarities are even more specific: For instance, spiders make their webs using a variety of silks with different sets of properties calibrated for different functions. Spiders make a type of silk to create the strong but flexible spokes of their web, a different silk that is sticky to capture prey, and another silk with good bonding properties that attaches the points of the web together. Ask your students: How is the fact that spiders use different types of silk for different purposes relevant to engineering? Based on the discussion, are your students able to figure out what the discipline of Materials Science is?
3. Work together to define the work of a Materials Science Engineer. By studying and understanding how materials work, Materials Science Engineers create new materials for new purposes as well as enhance existing materials to improve their performance, i.e., make them stronger, lighter, more heat-resistant, etc.

ACTIVITY
Distribute the "Drive Progress" activity sheet and explain to students that they'll research emerging materials, how they are used, and how they are manufactured. (There is plenty of information readily available online, and if desired, you can also use this as an opportunity to discuss credible sources.) In small groups, students will want to consider not only materials science but also the cost and environmental impacts while they make decisions about a fictional city's fleet of green-energy buses. Use the table below to help jump-start the learning or to lead the discussion at the conclusion of the activity.

CONSIDERATIONS	POINTS FOR DISCUSSION
Technology Electric vehicle Hybrid electric vehicle Hydrogen fuel cell vehicle	• Environmental pros and cons • Cost of technology and fuel • Issues with new and emerging technologies
Materials Carbon fiber reinforced polymer Metal foam Aerogel	• Interesting properties of each material • Application in green transit • Pros and cons of each material
Manufacturing Processes Carbon fiber reinforced polymer molding 3D printing Supercritical drying	• Process for manufacture • Pros and cons of manufacturing process • Current limitations

CONTEST | $1,000 CLASSROOM GRANTS
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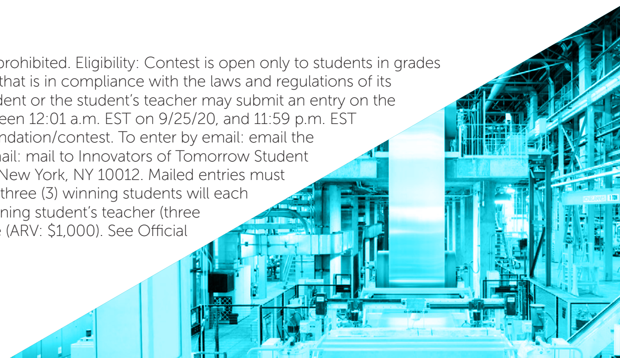

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Drive Progress

AS MAYOR OF ECO CITY, you are considering proposals for three green-transit bus options. Research the cost, the materials science, the manufacturing process, and the environmental impacts of each company's proposal below. Which buses would you select for your city? Use your understanding to award the transit contract to the most qualified firm.

FUEL YOUR THINKING

1 CONSIDER THE ENERGY SOURCE FOR EACH BUS.

What are the environmental benefits of each technology? What are some of the drawbacks?

2 CONSIDER EACH OF THE INNOVATIVE MATERIALS.

How are they used in transportation applications? What are their benefits? What are their drawbacks? Why are these materials especially useful in green-transit applications?

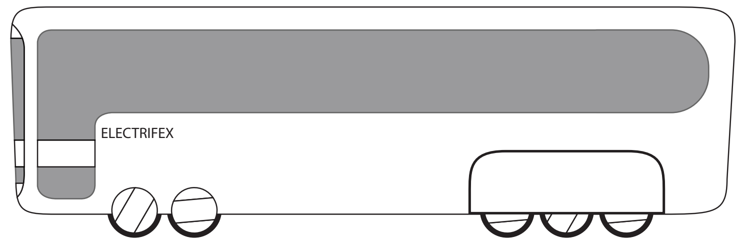
3 DO SOME CALCULATIONS.

What is the total cost of each bus once the additional cost of innovation is considered?

4 WHICH COMPANY WOULD YOU AWARD THE CONTRACT TO?

Provide your rationale, including the factors you compared and considered. What questions would you like to ask before awarding a final contract or making a final decision?

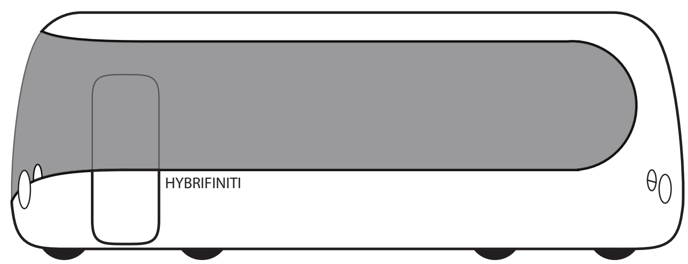
PROPOSAL: **ELECTRIFEX | Commute in step with community**



- **Energy Source** Electric
- **Innovative Material** Carbon fiber reinforced polymer
- **Innovative Manufacturing Technique** Carbon fiber reinforced polymer molding
- **Base Cost of One Bus** $800,000
- **Additional Cost of Innovation** Will use 4,022 units of polymer at a cost of $24.79 per unit.

Total Cost Per Bus $____________

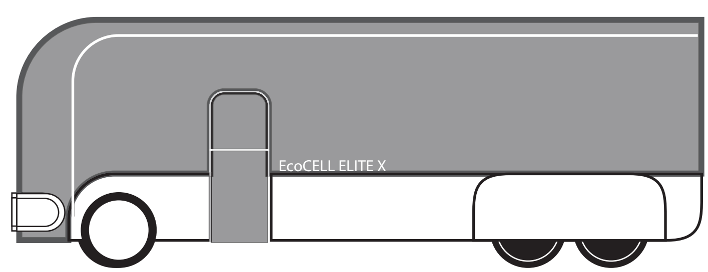
PROPOSAL: **HYBRIFINITI | A ride worth sharing**



- **Energy Source** Hybrid electric
- **Innovative Material** Metal foam
- **Innovative Manufacturing Technique** 3D printing
- **Base cost of one bus** $600,000
- **Additional Cost of Innovation** Will use 2,851 units of metal foam at a cost of $70.56 per unit.

Total Cost Per Bus $____________

PROPOSAL: **ECOCELL ELITE X | Innovations for an innovative world**



- **Energy Source** Hydrogen fuel cell
- **Innovative Material** Aerogel
- **Innovative Manufacturing Technique** Supercritical drying
- **Base Cost of One Bus** $1,000,000
- **Additional Cost of Innovation** Will use 890 units of aerogel at a cost of $112.16 per unit.

Total Cost Per Bus $____________

LESSON 3 Robots at the Ready

OBJECTIVE

Students consider how robots can be beneficial in manufacturing and perform a cost-benefit analysis to merge business thinking with STEM.

MATERIALS

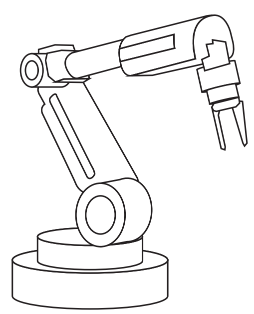
"Robot Reboot" activity sheet, internet access

TIME

75 minutes

CONTEST PREP

This lesson gives students a chance to practice business thinking in the context of robotic manufacturing.



ACTIVITY SHEET KEY

1. There is no single correct solution. Staying in budget, a maximum efficiency score of 19 can be achieved with three robots with an efficiency score of 6 plus one robot with a score of 1.

2. Students can share research on how robot functions might be beneficial for workers. E.g., 'Robot A' lifts heavy pieces that might be dangerous for humans to lift.

3. Students can share how they consolidated budget and efficiency score with prior knowledge, research, and personal judgment when making decisions.

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CLASS DISCUSSION

1. Show a short video of robots working on an automotive assembly line, such as bit.ly/2JNx4uW.

2. Ask your class if the arms in the video are robots or machines. What is the distinction between a robot and a machine? Prompt students that a machine performs a function, and a robot is a *type* of machine that can be programmed to *autonomously* perform a variety of functions.

3. Ask students to think about the video of the assembly line they watched. Besides performing a specific function, like driving a screw or lifting a piece into place, what are some of the reasons robots are used in manufacturing? Create a list together. Jump-start the list or complement students' ideas with the following robot functions:
   - handling repetitive tasks
   - working with small pieces or in tight spaces
   - working with large or heavy pieces
   - efficiency
   - working in unsafe or hazardous conditions for humans (such as extreme temperatures or heights)
   - ability to be programmed to perform complex functions and sequences and respond to changing conditions

ACTIVITY

Distribute the "Robot Reboot" activity sheet and explain to students that they'll be researching some of the functions robots perform in the manufacturing of vehicles. Students will work with a budget and make decisions about how to improve the efficiency of their fictional green-energy bus factory. There is no right answer as long as students can justify their choices.

Ask them to share their solutions and the rationale for their decisions. Are they able to figure out the maximum efficiency score? What factors besides efficiency are important to your students?

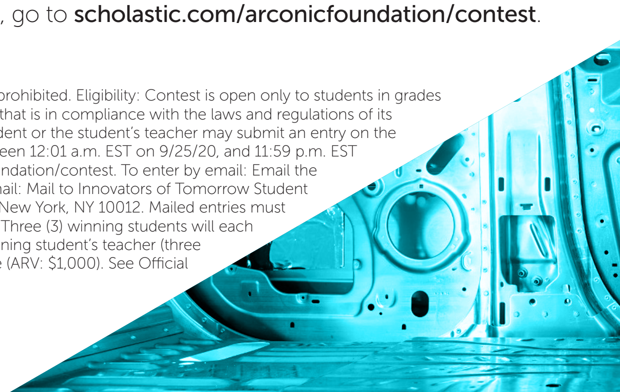
ENTER FOR A CHANCE TO WIN A $1,000 CLASSROOM GRANT!

Continue the learning with the Innovators of Tomorrow Contest. Three students in grades 9–12 will win a tablet, and their teacher will win a $1,000 classroom grant! You may wish to get students motivated by having them think about what they would do with a tablet, or what technology, supplies, or field trips they would suggest you purchase or organize if your classroom receives the $1,000 classroom grant.

Share the contest planner with students to help inform their entries. When students are ready, ensure they fill out and submit the two-part entry form.

It's recommended that teachers mail, email, or upload for an entire class, but students may submit on their own. For complete details, go to **scholastic.com/arconicfoundation/contest**.

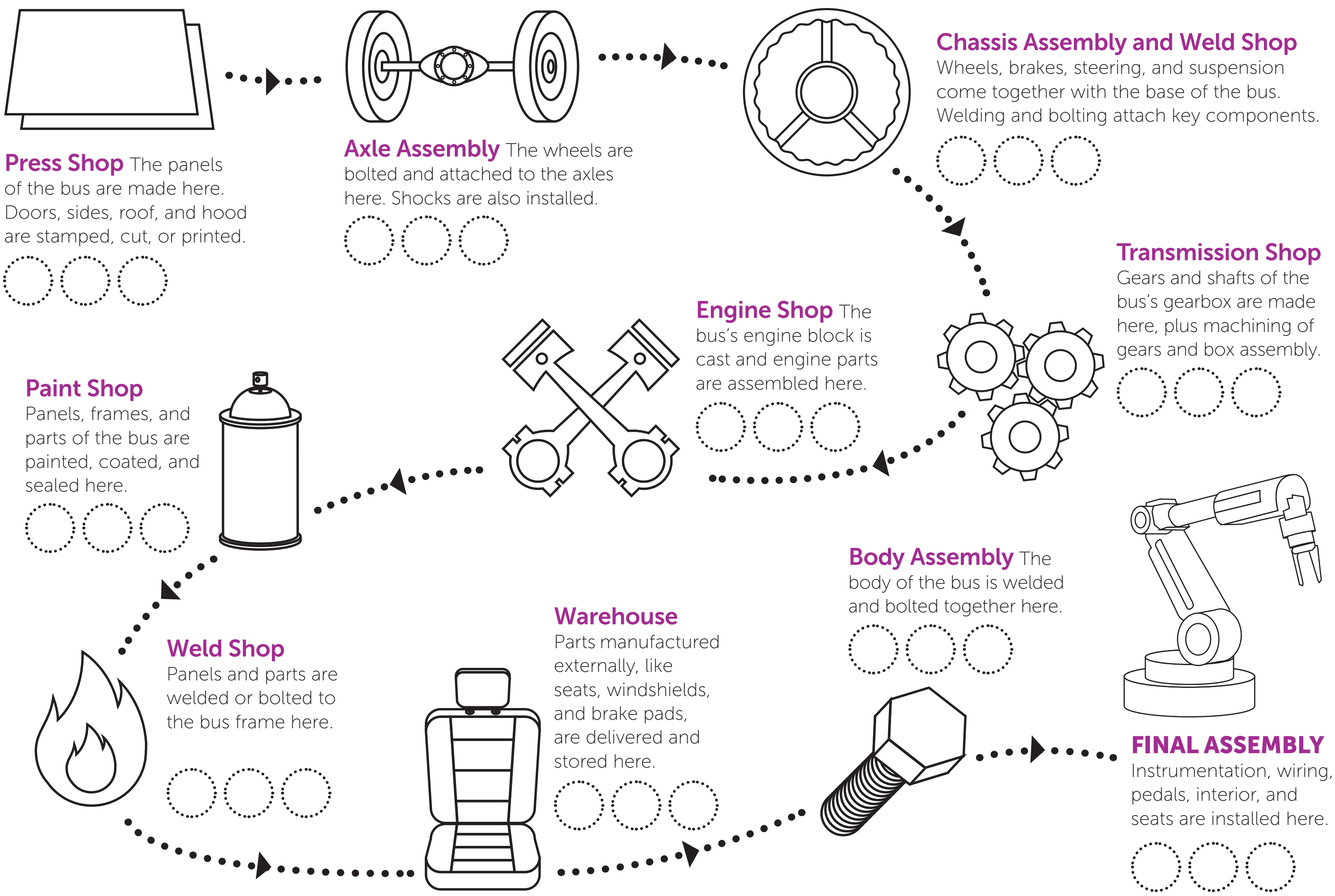
NO PURCHASE NECESSARY TO ENTER OR WIN. Void where prohibited. Eligibility: Contest is open only to students in grades 9–12 in a public, private, or home school in the 50 U.S. & D.C. that is in compliance with the laws and regulations of its state/district and who are residents of the above. Only the student or the student's teacher may submit an entry on the student's behalf. Entry period: Entries must be submitted between 12:01 a.m. EST on 9/25/20, and 11:59 p.m. EST on 12/14/20. To enter digitally: Visit scholastic.com/arconicfoundation/contest. To enter by email: Email the entry to scholasticsubmissions@scholastic.com. To enter by mail: Mail to Innovators of Tomorrow Student Contest, Scholastic Inc., ATTN: SNP, 3rd Floor, 557 Broadway, New York, NY 10012. Mailed entries must be postmarked by 12/14/20, and received by 12/22/20. Prizes: Three (3) winning students will each receive one (1) Amazon Fire HD tablet (ARV: $89.99). Each winning student's teacher (three [3] teachers total) will receive a $1,000 grant for classroom use (ARV: $1,000). See Official Rules at: scholastic.com/arconicfoundation/rules.



Name: ____________________

Robot Reboot

CALLING ALL ENGINEERS! A contract has been awarded for a fleet of green-transit buses in Eco City. Below is the flow of work at the Green Mobile Bus Factory as well as a selection of robots that can increase efficiency and/or improve safety. Your job is to research the robots and decide which ones are worth purchasing for Eco City. Assign up to three robots per area by writing their letter codes into each stage of the workflow. You may choose as many robots as you like, including buying multiples of the same robot, as long as you stay within your **$470,000** budget. Go!



CHOOSE FROM ROBOTS THAT CAN BE PROGRAMMED TO...

A Lift heavy pieces **Cost:** $40,000 **Efficiency Score:** 1	**B** Assemble smaller components like gear and motor parts **Cost:** $150,000 **Efficiency Score:** 6	**C** Laser-cut, stamp, or 3D-print parts/panels **Cost:** $120,000 **Efficiency Score:** 5
D Weld parts together **Cost:** $100,000 **Efficiency Score:** 3	**E** Mold parts or pour molten metal **Cost:** $50,000 **Efficiency Score:** 1	**F** Apply paint and sealant **Cost:** $110,000 **Efficiency Score:** 4
G Install parts **Cost:** $60,000 **Efficiency Score:** 2	**H** Pick and deliver parts from the warehouse **Cost:** $70,000 **Efficiency Score:** 2	**I** Work in tandem with a person **Cost:** $140,000 **Efficiency Score:** 6

Write your answers on separate paper.

1. How were you able to improve the efficiency of the factory? Add the efficiency scores of each of your robots. What is your total efficiency score? (Higher is better.)

2. Explain how the robots in your factory relieve humans of repetitive or tedious tasks, eliminate strain on the human body, remove humans from dangerous working conditions, or perform tasks that might be difficult for humans.

3. How did you make decisions about which robots to include and where to place them? Which decisions were difficult? Why?