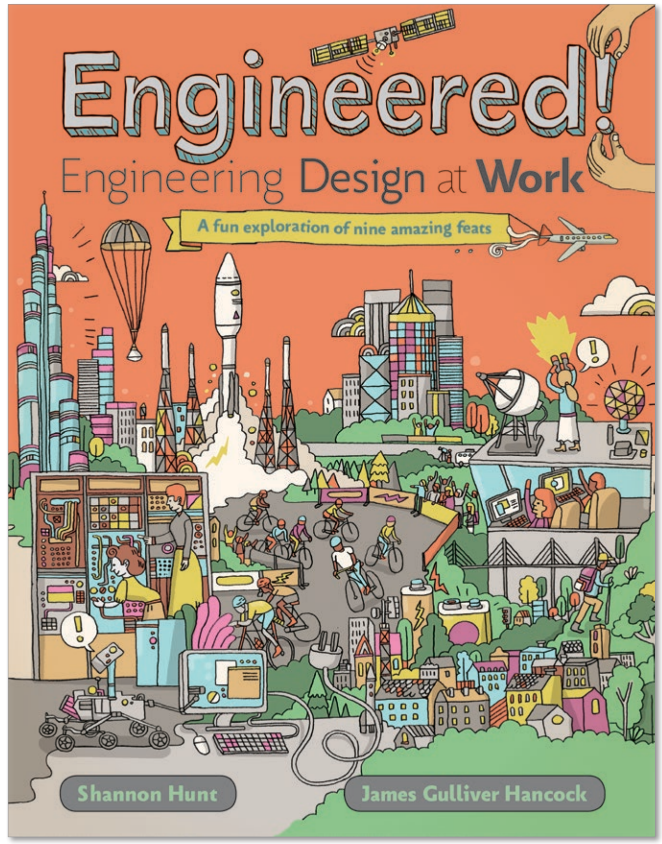
Engineered! – Teaching Guide

About the Book

How do you land a rover on Mars, resolve a perpetual traffic jam or save a herd of caribou from potential extinction? Ask an engineer! Author Shannon Hunt presents nine real-life problems for which engineers designed inventive (and even crazy!) solutions. Each was solved using a different field of engineering — from aerospace and mechanical to the new field of geomatics. A helpful seven-step flowchart of the engineering design process is also featured: define the problem, investigate the requirements, develop solutions, design a prototype, test it, improve it and share the idea. These steps are highlighted in each chapter with helpful icons that refer back to the flowchart. Sidebars, biographies of the engineers and fun detailed illustrations help flesh out the stories and bring them to life.

This terrific introduction to some fascinating practical applications of engineering is sure to inspire the natural engineer in every child. With its emphasis on real-world connections to the math, science and technology skills as well as the critical thinking and creative problem solving used in each example, this book is a natural for encouraging STEM education (science, technology, engineering, math). With so many direct curriculum applications for grades three to seven, and in following with the guidelines in the Next Generation Science Standards, this book is a perfect resource for classrooms and libraries, as well as anywhere a makerspace is found. Includes a table of contents, glossary and index.

Engineered! was selected as one of the Canadian Children's Book Centre's Best Books for Kids & Teens in 2018, was listed as a Eureka! Honor Award Book and shortlisted for both the 2018 Hackmatack's Children's Choice Book Award and the 2019 Silver Birch Nonfiction Award.



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About the Illustrator

JAMES GULLIVER HANCOCK's obsession with reimaging his world has led him to work on major print, TV and music publishing releases. He grew up in Sydney, Australia, and studied visual communications at the University of Technology Sydney. In kindergarten, he once devised the most complex drawing he could think of, refusing to move on to the next activity and instead detailing a complex illustration of a city of houses that included each detail, each person and each spider web between each house. He still has that drawing. In high school, he discovered technical drawing. He has always been obsessed with machines and the way things work, joining that with a childlike perception of the things around him. Currently he works out of two studios: one in The Pencil Factory in Brooklyn, New York, and the other from his homeland studio by the beach in Sydney, Australia.

About the Author

SHANNON HUNT grew up on a small sailboat in the Caribbean, a circumstance she blames for her aversion to all exercise except swimming and her ability to tell her stern from her bow — admittedly, not a particularly useful life skill. After an unusually long (ten-year) stopover in Florida, her parents packed up and moved home to Canada, settling on a small island in British Columbia. She co-founded two science magazines for kids, *YES Mag* and *KNOW*, winning a Distinguished Young Alumni Award from the University of Victoria, the Eve Savory Award for Science Communication from the BC Innovation Council, the Michael Smith Award for Science Promotion from Canada's Natural Sciences and Engineering Research Council (NSERC), and the Periodical of the Year from the Association of Educational Publishers.

Shannon is a co-editor of the nonfiction titles *The Amazing International Space Station*, *Fantastic Feats and Failures*, *Science Detectives*, *Hoaxed!*, and *Robots*, and the author of the fiction title *Peril on Pender*. She lives in Victoria, British Columbia, with her husband, two awesome kids and a crazy labradoodle — who all engineer equal parts magic and mayhem into her life.

Kids Can Press

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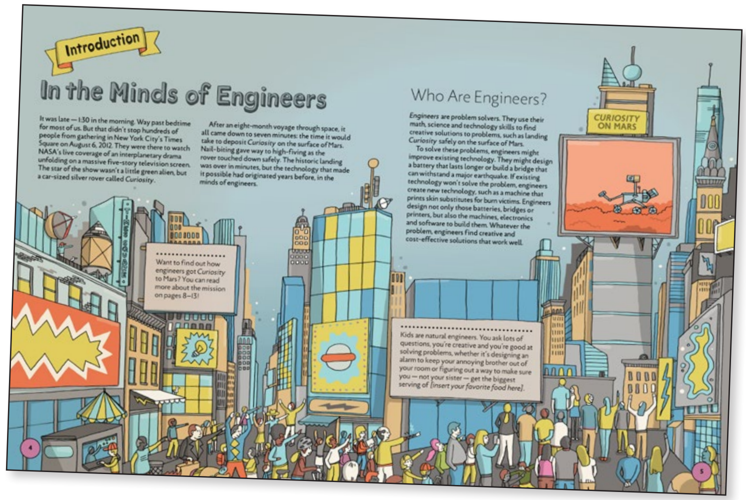
About This Resource



Engineered! is a long book with a lot of information packed onto every page. As such, the best method for using this resource is to assign the book as homework to students before you begin the activities.

For younger students, reading can be done in class with your support. Separate each chapter into one day's reading period and discuss the chapter with students afterward. Encourage students to use the glossary in the back when they get stuck and to jot down questions they have about terminology they can't find elsewhere.

Plan to spend about a week reading this book and completing the activities. If your students all read the book before completing Activity One, they will be better able to participate in the discussions that follow each presentation.

Activities Two and Three are more lighthearted and fun and as such can be completed in any order, at any time during the week, or after all reading and presentations have been completed.

Outline of Activities for Grades 3-7

Activity One: Small-Group Research and Presentation

Could take several class meetings to complete.

Activity Two: Individual or Small Groups — Rubber-Band Car Design Project

Give students an hour or more, as needed and depending on age.

Activity Three: Rube Goldberg!

If possible, encourage outside work and the presentation of projects in class.

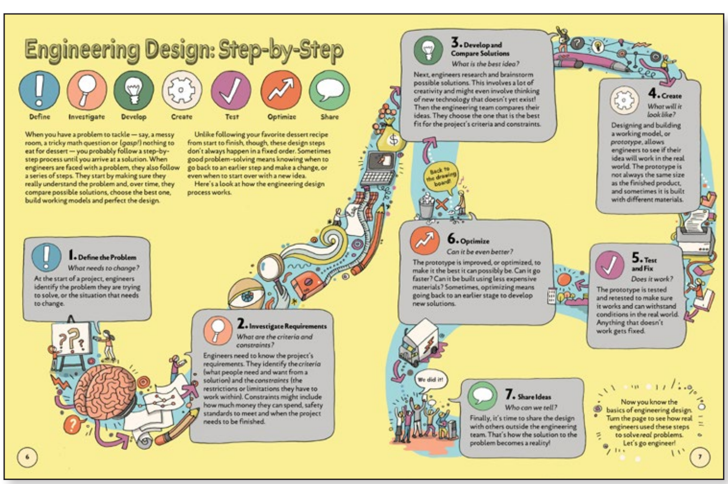
Activity One: Small-Group Research Presentation

Part One

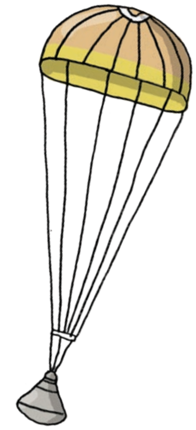
Choral read the opening pages (4–7) of *Engineered!* and as you do so, recreate on the board the Engineering Design: Step-by-Step chart found on pages 6–7. Leave this up for the duration of activities.

Break the students up into eight or nine small groups and assign each group one of the chapters:

- "Seven Minutes of Terror," aerospace engineering, pages 8–13



- "The Ultimate Print Job," biomedical engineering, pages 14–17
- "Double-A Idea," chemical engineering, pages 18–19
- "A Need for Speed," mechanical engineering, pages 20–23
- "The Tyranny of Numbers," electrical engineering, pages 24–27*
- "Engineering above the Clouds," civil engineering, pages 28–33
- "Not-So-At-Home on the Range," geomatics engineering, pages 34–37
- "The Wonderful Wizard of Woz," computer engineering, pages 38–39*
- "When Good Sewers Go Bad," environmental engineering, pages 40–45



*"The Wonderful Wizard of Woz" and "The Tyranny of Numbers" could be combined into one group if you have 16 or fewer students. In such a setting, place students in pairs and assign the shorter chapters to individuals who want to work on their own.

While the whole group is still together, explain the assignment.

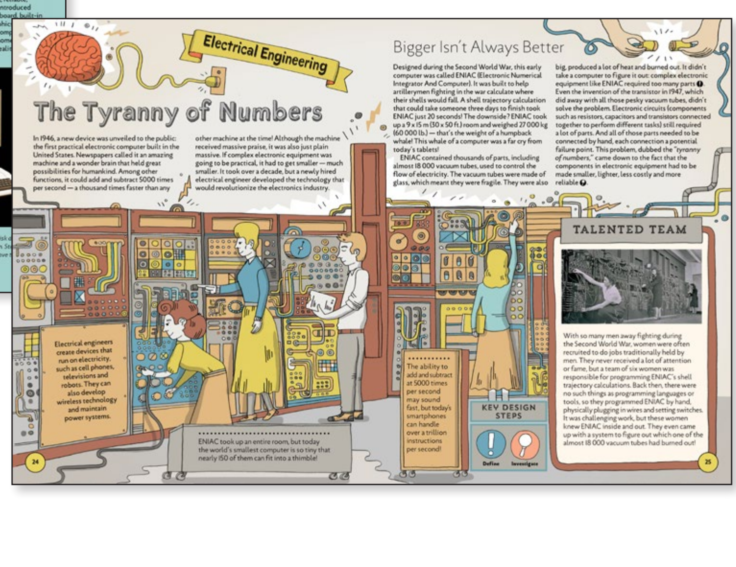
Students will be expected to:

- define the type of engineers who worked on the project
- describe the problem those engineers faced
- explain their process for coming up with a solution — and if they ever had to go back to the drawing board
- explain the solution
- talk about how that solution changed the world, or how it impacted people/improved lives

Note to Educator: For older students, assign outside research about the problem and solution described in their chapter. The outside research should result in a more complex understanding of either the problem or the solution (or both), and add information that was not presented in the book.

Make copies of the worksheet on the next page and distribute one copy to each small group. Explain that students should use this worksheet to take notes on each of the questions you have explained. They should work collaboratively — taking turns reading sections of their assigned chapter, keeping notes for the answers or doing outside research.

Allow students an hour or more to complete the assignment. You can break this up over several days, depending on your class style and the age of your students.



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TITLE OF CHAPTER: ______________________________

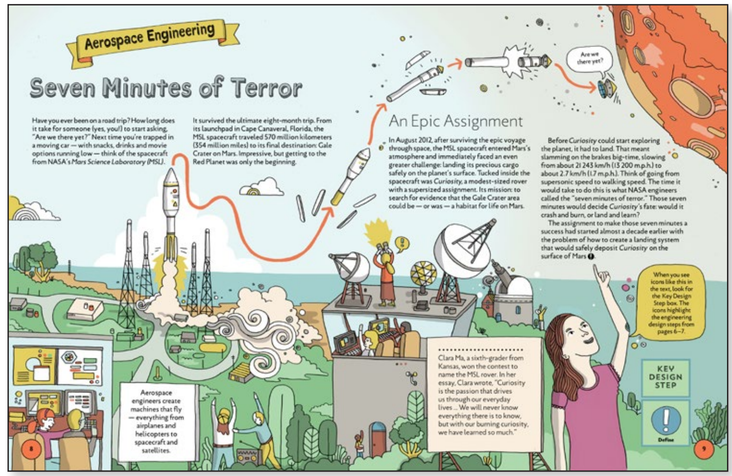
Type of Engineer and Definition	Problem Faced	Process for Finding Solution
Solution	**Effect on People/the World**	**Other Important Details**

Once each group has completed their worksheet, ask them to write short presentations about their chapters. Although students can use the book in their presentations, encourage them not to simply read it aloud, but to explain in their own words what the problem was and how it was solved.

For younger students, ask the group all of the questions in the bulleted list in order to focus their attention and energy. For older students, wait until the presentation is over to ask questions, and then open the discussion up to the group.

Suggested questions and discussion points for each chapter:

"Seven Minutes of Terror," aerospace engineering, pages 8–13



- How was the *Curiosity* rover named? If you were part of the competition to choose the name, what might you have wanted to call it?
- What do aerospace engineers make? Do they use any other kinds of engineering in their work?
- What was at stake if the *Curiosity* rover had not landed safely?
- Explain some of the possible solutions and why they wouldn't have worked.

"The Ultimate Print Job," biomedical engineering, pages 14–17

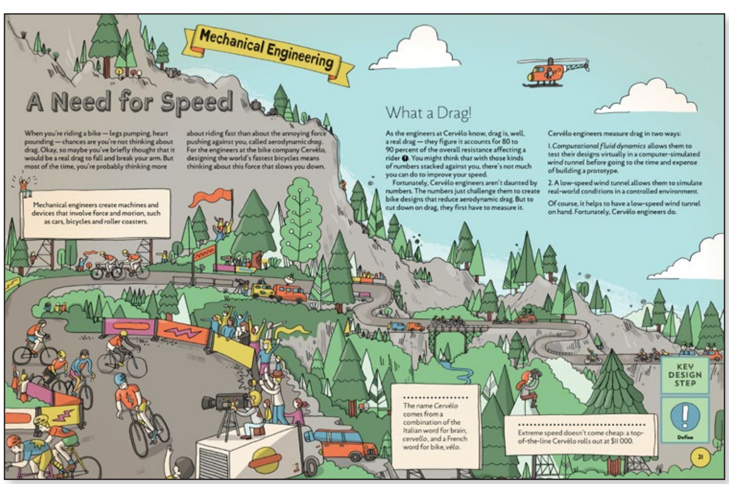
- What do biomedical engineers make? Do they use any other kinds of engineering in their work?
- Why did these engineers want to come up with a solution to replace skin grafts? What is wrong with skin grafts?
- How does the bioprinter work?
- Can you think of anything else that this technology might accomplish or make easier in the medical field or beyond?

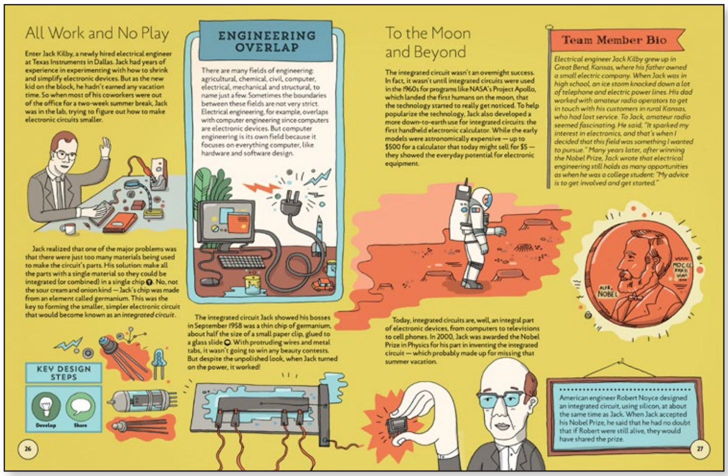
"Double-A Idea," chemical engineering, pages 18–19

- What do chemical engineers make? Do they use any other kinds of engineering in their work?
- Describe the difference between carbon-zinc batteries and alkaline batteries.
- What might have happened if Lewis Urry had not bought two battery-operated cars on his way to work that day?
- How would the world be different today if this type of battery had never been invented?

"A Need for Speed," mechanical engineering, pages 20–23

- What do mechanical engineers make? Do they use any other kinds of engineering in their work?
- What is aerodynamic drag? What other things might it affect besides bicycles?
- How was Foam Dave the test dummy helpful to the engineering process?
- Are there any other uses for the technology described in this chapter that might help people who don't ride fancy bicycles?





"The Tyranny of Numbers," electrical engineering, pages 24–27

- What do electrical engineers make? Do they use any other kinds of engineering in their work?
- What was one of the main problems with the electric circuits used in the ENIAC?
- Why do you think early calculators were so expensive? Why do you think prices on such items can drop over time?

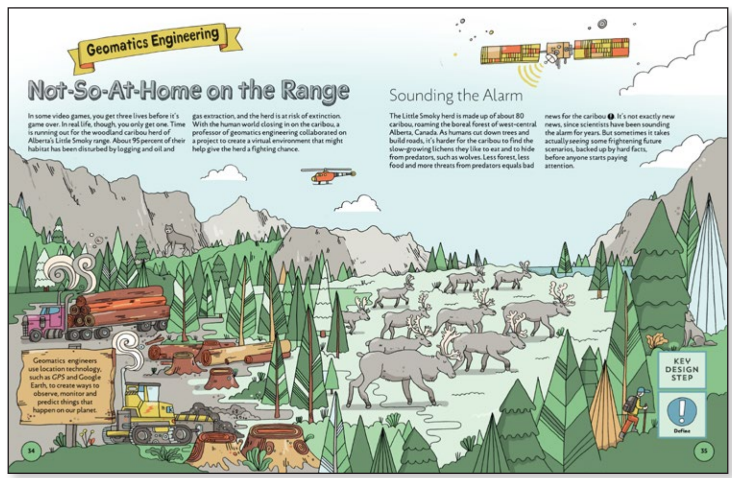
Note to Educator: You can combine this with "The Wonderful Wizard of Woz," computer engineering, pages 38–39

"Engineering above the Clouds," civil engineering, pages 28–33

- What do civil engineers make? Do they use any other kinds of engineering in their work?
- Describe the possible solutions in ideas 1, 2 and 3, and why they weren't good enough.
- Why do you think it was important to the people of Millau that drivers could still access the town?
- If you did outside research: how do drivers access the town from that bridge in the clouds?

"Not-So-At-Home on the Range," geomatics engineering, pages 34–37

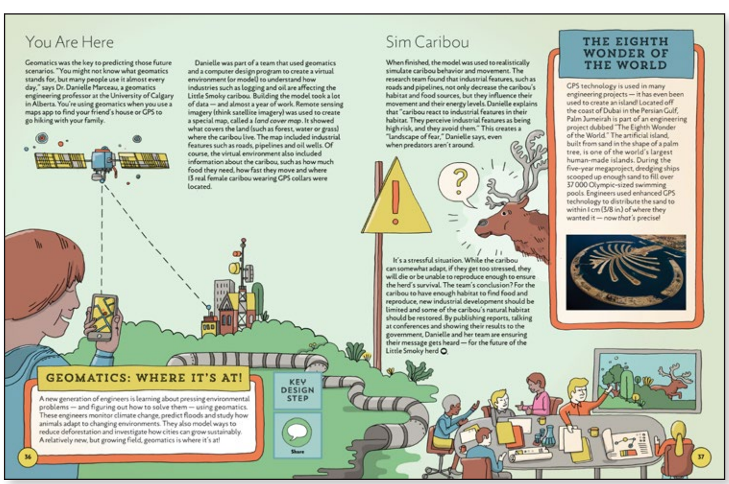
- What do geomatics engineers make? Do they use any other kinds of engineering in their work?
- When compared to projects about medical advancements or technological breakthroughs, how is this project different?
- What other kinds of things could geomatics engineers design, and what problems would they solve?



"The Wonderful Wizard of Woz," computer engineering, pages 38–39

- What do computer engineers make? Do they use any other kinds of engineering in their work?
- How did affordable home computers change people's lives, and how would your life be different if they hadn't been invented?

Note to Educator: You can combine this with "The Tyranny of Numbers," electrical engineering, pages 24–27



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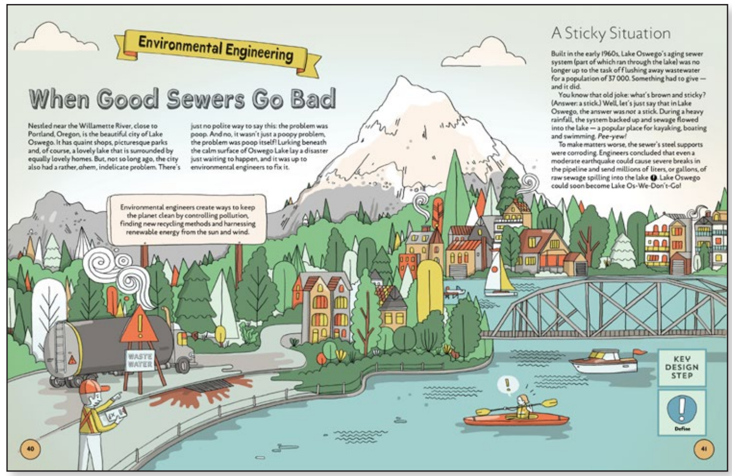

Environmental Engineering

When Good Sewers Go Bad

Nestled near the Willamette River, close to Portland, Oregon, is the beautiful city of Lake Oswego. It has quaint shops, picturesque parks and, of course, a lovely lake that is surrounded by equally lovely homes. But, not so long ago, the city also had a rather, *ahem*, indelicate problem. There's just no polite way to say this: the problem was poop. And no, it wasn't just a poopy problem, the problem was poop itself! Lurking beneath the calm surface of Oswego Lake lay a disaster just waiting to happen, and it was up to environmental engineers to fix it.

Environmental engineers create ways to keep the planet clean by controlling pollution, finding new recycling methods and harnessing renewable energy from the sun and wind.

A Sticky Situation

Built in the early 1960s, Lake Oswego's aging sewer system (part of which ran through the lake) was no longer up to the task of flushing away wastewater for a population of 37 000. Something had to give — and it did.

You know that old joke: what's brown and sticky? (Answer: a stick.) Well, let's just say that in Lake Oswego, the answer was not a stick. During a heavy rainfall, the system backed up and sewage flowed into the lake — a popular place for kayaking, boating and swimming. *Pee-yew!*

To make matters worse, the sewer's steel supports were corroding. Engineers concluded that even a moderate earthquake could cause severe breaks in the pipeline and send millions of liters, or gallons, of raw sewage spilling into the lake ❗. Lake Oswego could soon become Lake Os-We-Don't-Go!

"When Good Sewers Go Bad," environmental engineering, pages 40–45

- What do environmental engineers make? Do they use any other kinds of engineering in their work?
- Describe the constraints in this project, listing each and explaining why it was important to consider while planning the solution.
- What was unique about the final solution, and can you think of anything else this type of solution could be applied to?

During each presentation, encourage discussion and questions from the other students.

Part Two

Once all small groups have presented their work and answered your questions, pair up groups for further conversation about the challenges of design testing and engineering. The choice of pairings can be random, but your goal is to get groups talking about the big ideas in engineering and not the small details. As such, you don't want the group that studied computer engineering to talk to the group that studied electrical engineering, because they will likely get into the weeds of component parts and specific devices. A better combination would be to have the group that studied geomatics engineering talk to the group that studied biomedical engineering, or the chemical engineering group to talk to the civil engineering group.

Once teams are paired up, turn their attention to the Engineering Design: Step-by-Step chart on the board and on pages 6–7 of their books. Have each grouping come up with a list of problems they think might be solved through engineering design — it can be related to one of their topics, or not!

Using either scratch paper and pencil or computer programs, have these groups ask themselves the questions in the step-by-step chart:

1. What needs to change?
2. What are the criteria and constraints?
3. What is the best idea?
4. What will it look like?
5. Does it work? (This is hard to answer in sketch phase, but have students think their plans all the way through.)
6. Who can we tell?
7. Can it be even better?

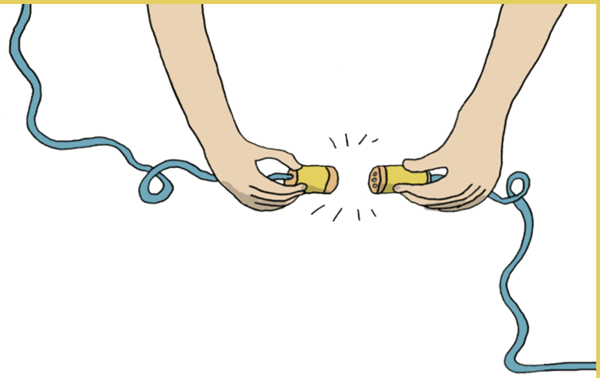
Activity Two: Individual or Small Groups – Rubber-Band Car Design Project

Provide each student (or small groups) with the following materials:

- cardboard
- compass (to draw circles)
- drinking straws (wide enough for a pencil to fit inside)
- nuts and bolts
- pencils
- popsicle sticks
- rubber bands
- scissors
- toothpicks
- white glue

Without providing students with directions, assign them the task of building a rubber band–powered car. Start by showing your students pictures of possible rubber-band car designs to allow students to reverse-engineer the design.

Note to Educator: The steps below are for your support, as students ask questions. However, there is no wrong way to build this car — anything with four wheels that can drive some distance on its own is a success!



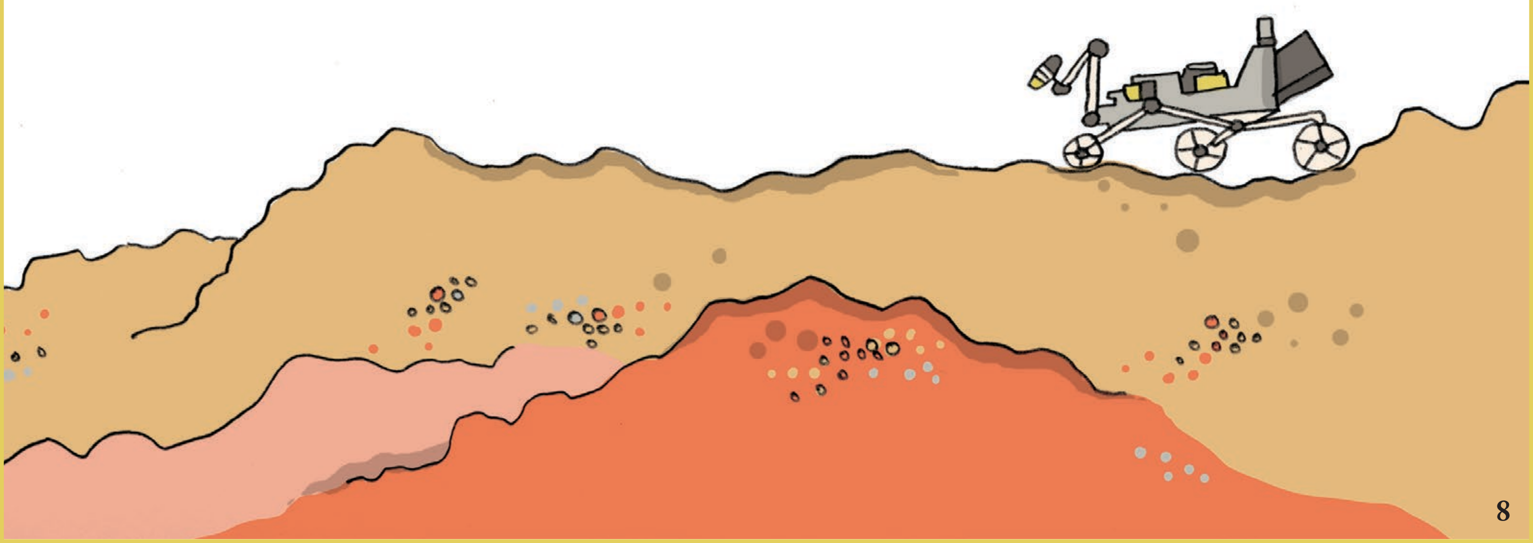
Throughout the process, remind students of the Engineering Design: Step-by-Step chart on the board and encourage them to try something new, and if it tests poorly, to go back to the drawing board. If time allows, let this activity spread over several days, as students will no doubt have great ideas when given a little time and space away from the project.

Possible Steps [STOP! Do not share these with students!]

1. Cut straw into four pieces.
2. Cut a toothpick into two small pieces.
3. Use the compass to draw four 50 mm diameter circles on cardboard.
4. Cut the cardboard circles out; these are the wheels.
5. Place rubber bands around the outsides of the cardboard wheels.
6. Cut holes in the center of each wheel, roughly the diameter of a pencil.
7. Stick one pencil into one of the wheel's holes, repeat with second pencil and a second wheel.
8. Slide two straw pieces onto each pencil.
9. Place a second wheel on the other end of each pencil; you now have two sets of wheels and axles.
10. Slide the pieces of straw to either end of each pencil, so all pieces touch a wheel.
11. Glue one toothpick piece to the center of each pencil, between the straw pieces; these will hold the rubber bands later.
12. Glue popsicle sticks onto the straw pieces, creating the bed of the car.
13. Decide which is the front of the car, and which is the back.
14. Glue bolts on the back of the car and screw some nuts onto each; this creates some drag.
15. Join two rubber bands together by looping one through the other.
16. Let all the glue dry before taking the next steps.
17. Attach one end of the joined rubber bands to the toothpick piece on the front of the car.
18. Attach the other end of the rubber band loop to the back toothpick piece.
19. Drag the car backward so that the elastic winds around the back pencil.
20. Release and watch the car go!

When everyone has completed the project, host a car show and let each person or team show off their cars' abilities.

Discuss if there were other ideas and how successful each one was. Ask students to comment on the process of creating something with limited supplies and no directions.



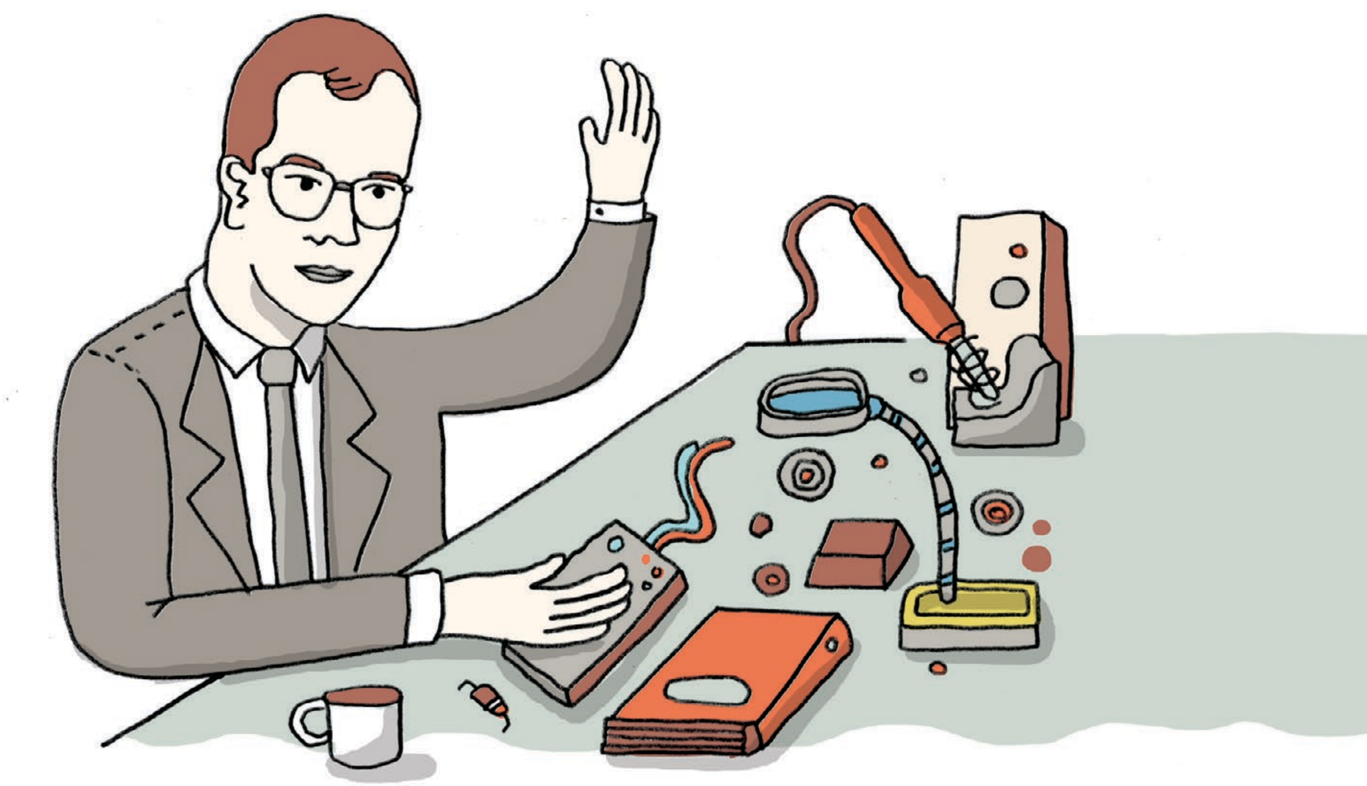
Activity Three: Rube Goldberg!

If possible, encourage outside work and the presentation of projects in class. **Note to Educator:** Unless students have extra time and enough resources, this activity will result in a drawing of designs, not the building of an actual Rube Goldberg Machine.

Explain to students that the purpose of engineering is to solve a problem in the most efficient way possible, coming up with a solution that is easy to use or implement, and which improves people's lives. Sometimes, however, it's fun to do the opposite! And much can be learned from having fun — including, sometimes, figuring out something unexpected through trial and error, laughter and silliness.

Reuben "Rube" Goldberg was a cartoonist and inventor who lived from 1883 to 1970. He was best known for a series of cartoons featuring Professor Butts, whose inventions solved simple problems in the most inefficient, overly complicated and hilarious ways. One such example was a cartoon of the professor getting sand out of his shoes as he walked on the beach. It involved fans, crabs and suction devices!

Goldberg became so famous for these cartoons that the phrase "Rube Goldberg" is now an adjective used to describe such an invention as well as anything foolishly overcomplicated. There are several annual competitions to create Rube Goldberg machines, including a recent one in which the task was to put money in a piggy bank. The winner's Rube Goldberg machine did that in the least efficient, most hilarious way.



Note to Educator: Photocopy the next page for students if assigning the task for outside work.

When students return to class with their sketches, have each one give a five-minute presentation explaining their Rube Goldberg machine. Ask them to reflect on how it felt to make a simple task more complicated. Ask them if they think the experience might help them design something more efficiently someday — and, if so, how and why.

Now it's your turn! Sketch a Rube Goldberg machine.

Step 1: Think of a simple task. Turning off a light, putting on a sock, putting two Lego blocks together or putting a stamp on an envelope. These are just some of the simple chores we complete each day, chores that can be made complicated and silly with a Rube Goldberg machine!

Step 2: Now imagine all of the ways you could complicate that task. Maybe a rubber band snaps, setting off a set of dominoes, which end at a marble that gets pushed down a chute, and after a complicated journey that marble ends up being propelled through the air and landing perfectly on the light switch, triggering it to turn off.

Step 3: Draw your Rube Goldberg machine in all its glory. Use the rest of this page to sketch out your initial ideas, and once you have everything more or less thought through, complete a large design sketch on separate paper.

Step 4: Bring your sketch into class and be prepared to give a presentation about the task you have complicated and made silly with your Rube Goldberg machine.