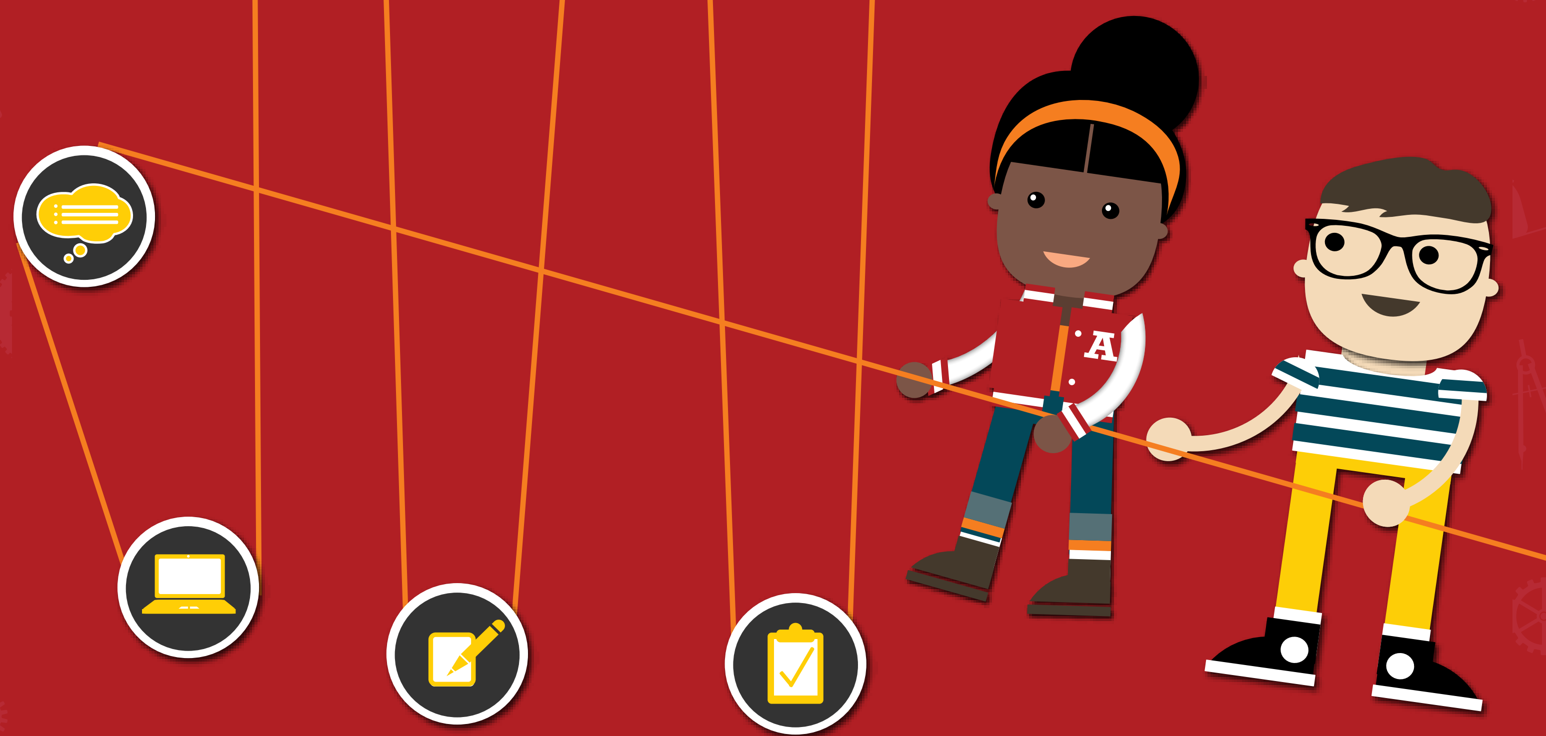
ENGINEERING EXPLORATION CHALLENGE

Educator Toolkit

Follow the Engineering Process
to Complete the Challenge



NATIONAL GEOGRAPHIC KIDS

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Visit www.NatGeoEd.org/NGX for more information on the Engineering Exploration Challenge.

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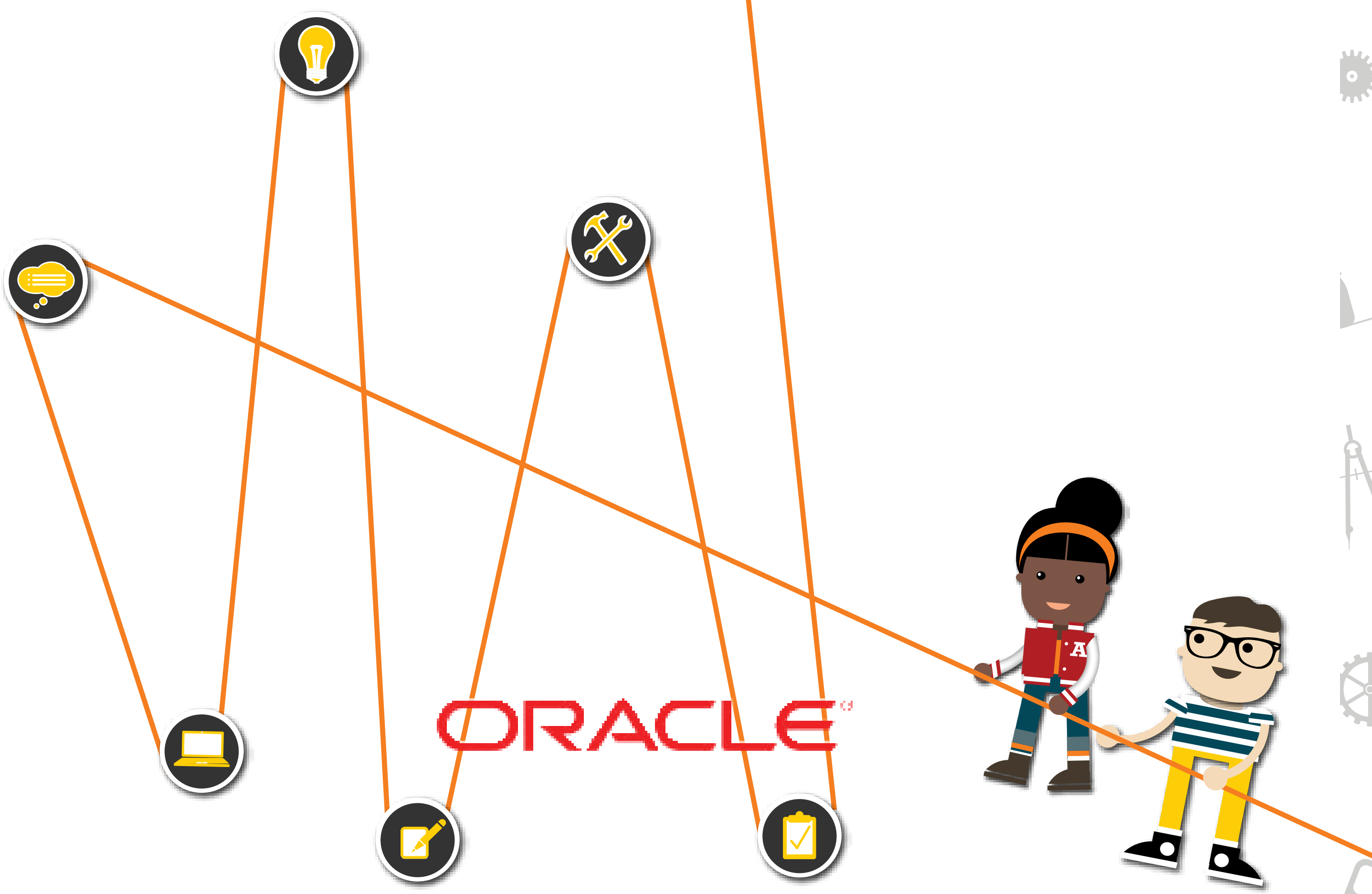


Dear Educator,

National Geographic invites you to challenge your students as engineers by participating in the Engineering Exploration (NGX) Challenge. The NGX Challenge provides three separate engineering challenges, each based on real-world challenges faced by National Geographic explorers in the field. In the first challenge, students design a way to protect a camera from an animal of their choice. In the second challenge, students design a way to raise a camera ten feet in the air and get it back down safely. In the third challenge, they design a way to charge electronic equipment in the field.

The NGX Challenge is designed for use with students from ages six to 18 in both formal and informal educational settings. The challenges are a good fit with any education program with a focus on, or interest in, promoting science, technology, engineering, and mathematics (STEM) program. They address the engineering design standards in the Next Generation Science Standards, and because they ask students to document each step of the engineering process, they also provide an excellent way to address the Writing in Science and Technical Subjects standard from the Common Core Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects.

In a classroom setting, the engineering challenges can be integrated easily into existing science curriculum. To participate in these challenges, students must do more than practice engineering. They must also apply their knowledge of biology, animal behavior, physical science, electricity, and more. Adapt the challenges to work within your curriculum. Emphasize the background research on animals to integrate with life sciences. Focus on the mechanics of the solution to integrate with a unit on the physical sciences. Use the charging equipment challenge as part of a unit on circuits and electricity.

Have students work in teams within your classroom to design, build, and test their solutions while using the engineering process. Encourage other classes to get involved in the challenge and then arrange for students to share their final solutions with students from other classes. Even if some solutions are unsuccessful, the students will be able to discuss how they might modify their solution to make it successful. Moreover, seeing the different ways other students approached the same challenge will be a valuable learning tool for all.

The NGX Challenge is also a good fit for a variety of informal education settings. Afterschool programs provide an excellent opportunity for students to work in teams to design, build, and test solutions. Host a demo day for students in your afterschool program to share their solutions with each other and to celebrate the many different approaches possible for the same problem.

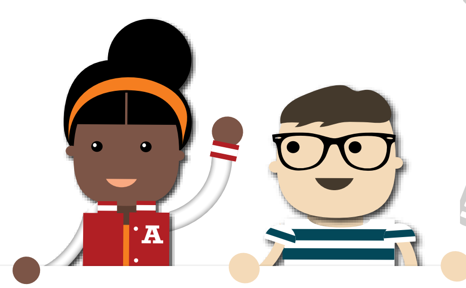
Museums and libraries can help build enthusiasm for the NGX Challenge, as well as provide a place for students to share their solutions. Host a kick-off party for the challenge and show the videos that introduce each challenge. Depending on your organization's focus, you might also offer question and answer sessions with experts in related fields during the course of the challenge. Provide workshop space and tools for students to use as they build their solution, and host workdays for students working on the challenge. At the end of the challenge, host an engineering expo and invite students to bring in their solutions to share with each other. You might ask participating schools to send representatives or open it up to the general public.

This Educator Guide provides all of the information you need to get your students started. The following pages contain general tips on how to address the challenges for both older and younger students, as well as specific tips and suggested materials lists for each challenge to help you get started. The student workbook pages are also included with annotations about how to integrate the engineering process into your classroom.

The NGX Challenge is an excellent way to motivate your students to be problem solvers and engineers. We look forward to the innovative solutions they will create!

Happy exploring!

National Geographic



General Tips for Challenges

Warm-Up Problems

Keep these general tips in mind when facilitating any of the three NGX Challenges.

- **Warm-up!** Provide some warm-up activities to get students thinking like engineers. For example, have students design a tower made of toothpicks and tape that will hold as many pennies as possible, or have them use simple materials to move a ball from point A to point B without touching it. Use a warm-up activity that relates in part to the challenge your students will work on.
- **Fail to succeed.** It is OK for students' designs to fail. Failing is an important part of the engineering process. The emphasis should be on the problem solving and engineering processes, rather than on having a perfect solution.
- **Safety first.** Always check students' designs to be sure they are safe to build before allowing them to move on to the building phase.
- During the building phase, make sure that students are supervised. If they are using tools, they must know how to use them safely and have the appropriate safety gear. If, at any point, you think they are being unsafe, stop the building phase.
- **Let students own their ideas**. Avoid telling students how to fix problems with their designs. Instead, use questions to stimulate their thinking. For example, ask open-ended questions such as "What are some other materials that might work?" instead of leading questions such as "Do you think screws would work better than nails?"
- **Use resources wisely.** In the testing phase, maximize your materials by having students create a smaller prototype of their solution to test for proof of concept. This will keep you from wasting larger or more expensive items in this early phase. Once they have proof of concept, you can then procure the items they will need to build their actual solution. This will save both time and materials.
- **Build testable solutions**. Students' solutions can be simple, but they should be testable. An elaborate model of a charging device made out of cardboard might get the idea across, but students won't be able to test it and re-engineer it. Having a testable prototype, even if it is not successful, is an important part of the process.
- **Consider group size**. Have students work in small groups to help emphasize the collaborative nature of engineering. Collaboration will also enhance creative thinking by bringing in multiple viewpoints. Keep groups small enough that all students get to be hands on. Groups of three to five work well.
- **Peer review**. If students are working on the challenge individually, plan in some time for peer sharing and review at the design level and again during testing. Have students ask questions about the design or prototype and give feedback on ways to improve it.

Tips for Younger Students

- Younger students may benefit from exploring available materials before they design their solution. Provide suggested materials early on for students to explore, but allow students to bring in or request additional materials as well.
- Students may design something that is far beyond their ability to actually build or that requires tools they can't safely use. If this happens, ask students what changes they will need to make to build the design themselves and allow them time to revise their plan.
- Allow younger students to repurpose objects to meet the challenge. For example, younger students may take advantage of an existing pulley or building blocks system.
- Plan at least **eight to ten hours** for elementary students and **five to seven hours** for middle school students to complete each challenge, with more time for gathering materials. The design and research phases can be done in one-hour time blocks. If possible, give students a longer time block—at least two hours—for the actual building, testing, and re-engineering of their prototype. They may need a follow-up session to complete re-engineering and testing to allow time to gather any new materials.

Tips for Older Students

• Providing materials at the onset of the challenge may be limiting to older students. Instead, have them design their solution and then provide you with a list of materials they will need. If they request materials that are too expensive or otherwise unavailable, have them go back and propose alternatives. You can use the suggested materials list to plan ahead for what you might need. However, if students struggle to generate ideas provide them with some materials to explore and jumpstart their thinking.
• Older students may require more time during the testing and re-engineering phase than younger students. The more sophisticated the design, the more things can go wrong. Be sure to allow ample time for students to address problems and re-test. Plan at least eight hours, plus outside time for gathering materials, for students to complete the challenge. More advanced solutions may require even more time. If possible, plan a long time block—three to four hours—for students to build, test, and re-engineer their prototype. Also plan for a follow-up session to allow time for students to gather additional materials they may need.

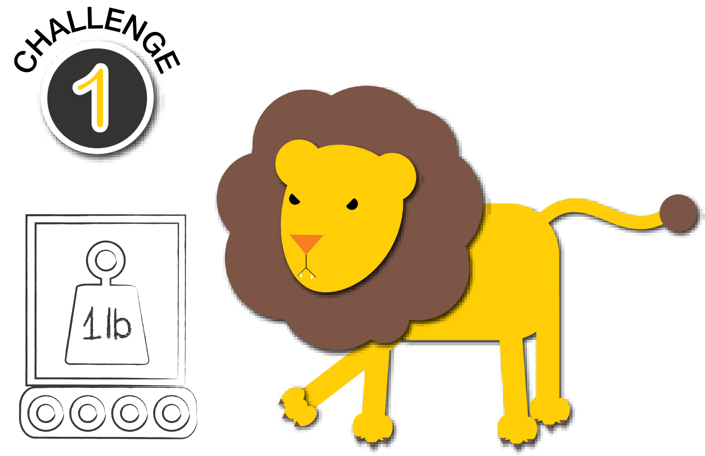
Tips for Each Challenge

Challenge 1

Challenge 1 asks students to solve a problem National Geographic photographers often face in the field: how to protect a camera from curious animals. The challenge is open-ended so students can choose any animal as the focus of their design. Though the challenge is the same for all students ages six through 18, students' solutions and approach to solving the problem will vary greatly at different ages.

Suggested Starting Materials

• duct tape
• cardboard
• PVC pipe
• paint
• balloons
• zip ties
• foam
• bubble wrap
• batting
• recycled materials such as soda bottles and cans



Tips

• Have students generate ideas about some different animals they would like to photograph and select one animal on which to focus their design. They should include the animal when they define the problem.
• As students research their animal, have them take notes about any relevant facts, such as the animal's size, behavior, etc. Encourage students to use specifics about the animal when defining the problem.
• At the beginning of the challenge, provide students with a one-pound weight that they will use to simulate the camera. If you do not have one-pound weights available, you can use full soup cans or bags of dried beans.
• Students will need to devise ways to simulate their animal's interaction with the camera in order to test their design. Encourage them to use specific information about the animal when designing their tests. For example, if an elephant stepping on the camera is a concern, then a test might involve placing weights equal to an average elephant's weight on top of the camera.
• If the problem seems overwhelming to students, encourage them to focus on one aspect at a time. For example, younger students may focus on protecting a camera from a tiger's swat, rather than on all the possible ways a tiger might damage the camera at once.
• Encourage older or more advanced students to design different tests for different ways an animal might damage the camera. For example, older students might have both a "swat test" and a "bite test" for a camera to be used with a tiger. Additionally, advanced students might consider how to operate the camera while it is in the protective unit they have designed.

Challenge 2

Challenge 2 asks students to devise a way to record and document places they can't normally see. Specifically, their challenge is to raise a camera ten feet in the air and lower it down again, all while students remain on the ground. Students will also need to think about how they will know when the camera has reached ten feet.*

Suggested Starting Materials

- duct tape
- cardboard
- PVC pipe
- recycled materials such as soda bottles and cans
- zip ties
- string/rope
- rubber bands
- hinges
- carabineer
- plastic containers

* Avoid any material that is already ten feet long.

Tips

- Begin by having students generate ideas about all the ways something could be lifted into the air. Encourage different approaches, such as being hoisted with rope, lifted by a crane, flying in a plane, and even bouncing off a trampoline.
- If students already have an idea for an approach to the challenge, they can focus their research on that approach. Alternatively, students can come up with research ideas based on the idea-generating session. Encourage students to research both nature and machines.
- At the beginning of the challenge, provide students with a bean bag or other item they will use to simulate a camera. Be sure the item is soft and light weight so it won't cause injuries if it falls.
- If possible, let students determine how they will know when their camera has reached ten feet as part of their testing process. One simple way to test teams' solutions is to measure and mark ten feet on a wall. Another way is to measure ten feet of string and attach it to the camera.
- You can encourage more creative risk-taking with older or advanced students by eliminating certain solutions. For example, you might add as a constraint that the camera cannot be lifted on a pole of any kind.

Challenge 3

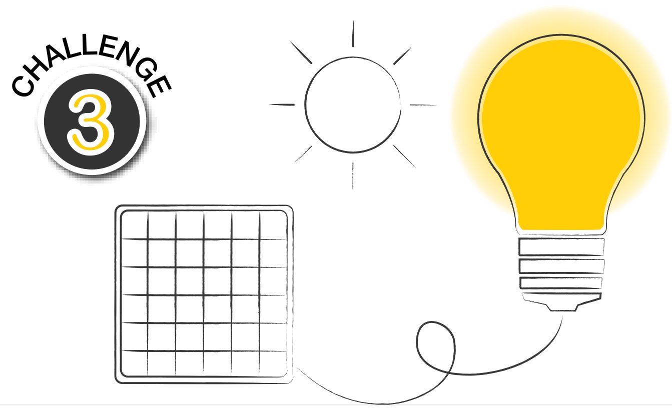
Challenge 3 addresses another challenge that explorers encounter in the field: how do you charge electronic devices when you are in the middle of a desert or jungle? This challenge asks students to design a wearable way to generate 1 watt of electricity without the aid of a battery or power outlet.

Suggested Starting Materials

- LED bulbs with leads or small bulbs with bases
- electrical wire and coils
- electrical tape
- needle-nose pliers
- small solar panels
- small generators or motors
- wire cutters
- lemons or lemon juice
- salt
- magnets
- bare copper wire
- pinwheels
- volt meter
- building blocks

Tips

• Supply students with wires and a bulb for testing. You can use an LED bulb with leads to which wires can be directly attached. You can also find bases with leads. Small bulbs can be screwed into these bases, and wires can be attached to the leads. All of these items can be found at an electronics supply store.
• Review safety rules for working with electricity before your students begin building or testing their solutions. Check students' designs for safety before allowing them to proceed to the building phase. Only allow students to test their designs while an adult is present.
• To prepare younger students or students with less background knowledge for this challenge, provide some basic hands-on experiences with electricity before introducing the challenge. Some examples include experiments with static electricity, creating simple circuits, creating a lemon battery, and generating an electrical charge with a magnet and coil.
• For students with more background knowledge, you may want to start by having them create a way to test their solutions. Give students the light bulb, some wire, a battery, and electrical tape. Have them create a circuit to power the light bulb. This can serve as a review for students, and when they are ready to test their solutions, they can just replace the battery with their device.
• List different ways electricity is generated, such as wind, solar, water, or fossil fuels. Have students research how these different kinds of power plants work. Discuss ways mechanical energy and chemical energy can be converted into electrical energy.
• Bring in some examples of things that get their power in different ways. For example, a flashlight that is powered by shaking or a calculator powered by solar energy. If possible, allow students to deconstruct these items to see how they work and repurpose their components.



• Students can approach this challenge in ways that require more expensive components, such as generators, motors, or solar panels. However, it is possible to work on the challenge without spending too much money. For example, students might create their own generator out of magnets and wires, or make a battery from saltwater or lemon juice. Students may be able to bring in items from home. You can also check thrift stores and junk yards for items that can be repurposed.
• Some solutions may not generate enough electricity to light a bulb. If possible, use a volt meter so students can see if they are generating some electricity with their solution, even if it isn't enough to light a bulb.

Using the Engineering Process Workbook

The following pages include the student workbook for the NGX Challenge with annotations for the teacher. Below are some general tips for integrating the workbook into your work with students. Using the workbook is an essential part of the engineering process because it allows students to record their work. Being innovative and creative is a messy business, and the workbook acts as a guide. It allows students to reflect on the individual steps of the engineering process.

• Use as much or as little of the workbook as is appropriate for your students.
• The workbook can be used as a guideline for what should be accomplished in each class period or session. For example, students can define the problem and do research in one class period or session and propose and design a solution in a second class period or session.
• Plan workbook breaks as students are building and testing their solutions. If students are working in one-hour blocks, the workbook break can take place in the last few minutes of the hour. If students are working in longer time blocks, plan a short break once an hour. Have students step away from their projects to record their progress in the workbook.
• Older students may prefer to use the Engineering Process handout. Have students record their work in a notebook.
• The Engineering Process workbook and Engineering Process handout can be downloaded at NatGeoEd.org/NGX.

Define the problem

Define in your own words the problem you need to solve.

- Have a few students share how they defined the problem. From the very beginning, students can see differences in how people approach a challenge.

Make a list of the requirements for your solution.

- Encourage students to think through the requirements carefully and be very specific.
- Requirements should go beyond the basic parameters given outright in the challenge to include constraints inherent in the challenge. For example, requirements for Challenge 1 might include that the solution be strong enough to support 50 pounds, or whatever is the average weight of the animal they choose. Requirements for challenge 3 might include that it be light-weight so it can be carried easily.
- Give students additional requirements to meet your budget and time constraints as needed.

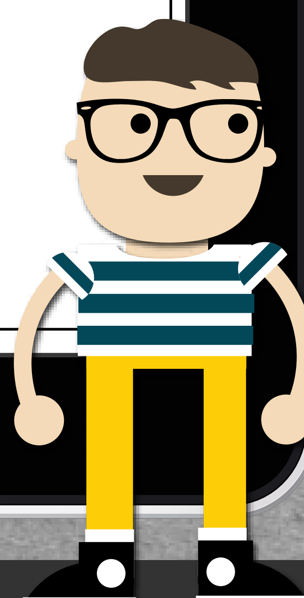
What difficulties do you think your team will have?

Do your research

List questions you have in the left-hand column. Then do research and write the answers in the right-hand column.

Questions	Answers

- Have students generate initial questions they have about the topic and write them down. As they research those questions, they can add other questions that come up.
- Students can conduct research outside of class time so that more class time can be used to build, test, and re-engineer students' solutions.



Propose a solution

Write a summary of your proposed solution.

- Encourage students to be detailed with their written proposal. Students should include an overview of how their solution will work as well as how their solution will address the requirements of the challenge.
- Students' proposals may be more sophisticated than they can actually build. At this stage, that is fine. Students can address this in their testing plan.

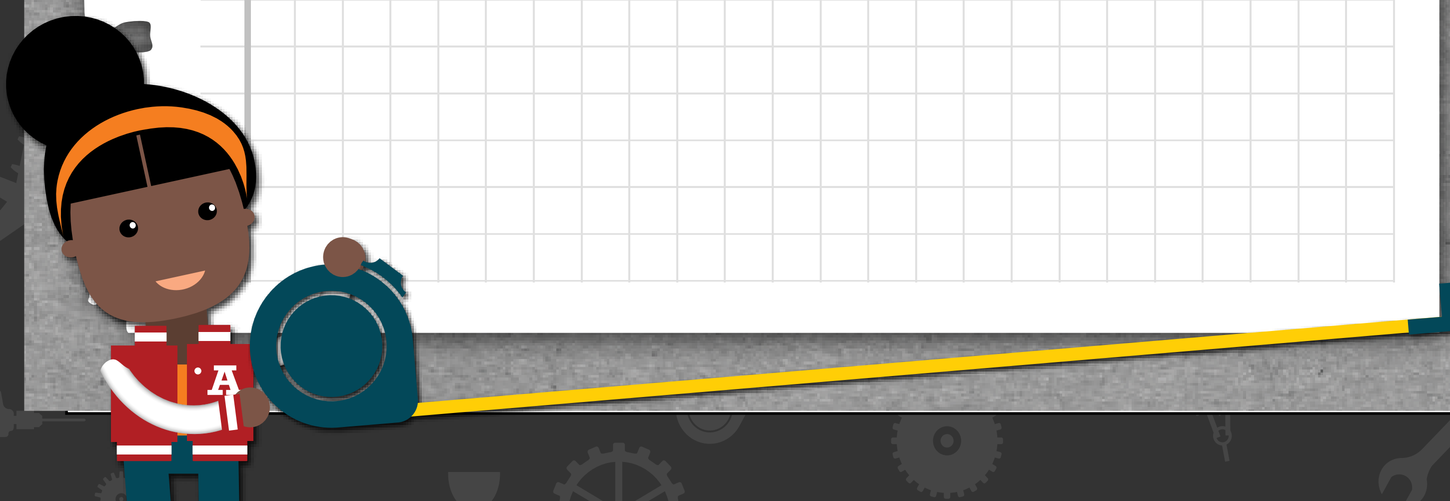
How will you test your solution to see if it works?

- Students' testing plans should include any materials they will need for testing.
- Testing plans should also include the data students plan to collect during testing and how they will record that data. For example, they can include a blank chart on which to record data.
- Students may need to consider prototyping or testing specific parts of their proposed solution to make it practical to build and test.
- Check in with students at the proposal stage to make sure they are proposing something that they can actually build and test. For example, they may have proposed a large solution. Can they make and test a smaller prototype? They may have proposed materials that are outside of your budget. Can they use less expensive materials in their prototype?

Design your solution

Draw your solution.
Label materials and include measurements.

- Encourage students to think of their design as a blueprint. Is it detailed enough that they could give it to someone else to build?
- When students have completed their design, have them list all the materials and tools they will need to build it.
- Review students' designs with them before the building phase. Look for any potential safety problems, and check the materials list for any items that you may not be able to provide. Have students revise their plans to address any issues before moving on.



You've designed it,
now create it!

Build your solution

- Take safety precautions. Go over safety rules for any tools before students begin building.
- If students will be using tools that require supervision, set up those tools in a specific location and have students come to the tool to use it, rather than taking it back to their work area. This makes it easier to supervise.
- Consider arranging for extra adult help during the building phase.

Test your solution

Draw your testing set up. How will you test your solution?

Test your solution and record notes from your testing. Did it work? If not, why?

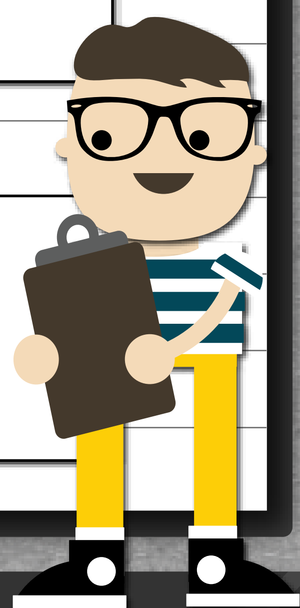
- Students may need to revise tables or charts they created in the planning phase after their first test.
- Check in with students as they are testing to make sure they are recording the information they will need going forward. As students improve their designs, they can use this data to track improvements.

Determine what changes you need to make to improve your solution, then make them. Retest. Did it work? If not, why?

- Have students analyze any problems they find in testing before making any changes. Why didn't it work? What specific aspect of the design was a problem?
- Encourage students to document the changes they make. Sometimes changes can create new problems. By documenting each stage of changes, students can go back to an earlier design point if needed.
- Be prepared for students to need additional materials during this time.

Repeat this process as many times as necessary.

- Depending on the time you have allotted for this project, it may not be possible for students to reach a point where their design is fully functional. If time is limited, students can write a brief proposal on their next set of changes and retesting.



TEST

What now?

Once you are satisfied with your solution, answer the following questions:

- If possible, allow a day or so between when students finish the challenge and when they complete this analysis.
- Have students look back at the data from their tests and at the documentation of their changes to help answer these questions.
- If students had a solution that did not succeed, encourage them to be specific about what didn't work and how it could be done differently.
- Ask students to share their results and reflections with other student groups or individuals.

Describe how your solution solves the challenge.

How does your final solution differ from your first design?
What changes did you make?

What worked well and why?
If you did this challenge again, what would you differently?

As an explorer, how would you use your solution in the field?
Where would you go and for what purpose?