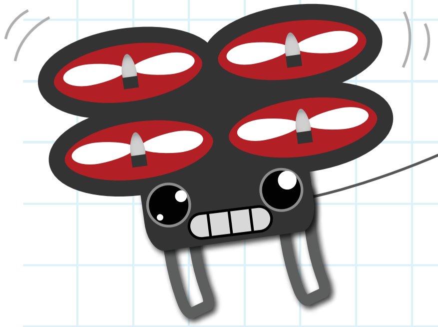
ENGINEERING EXPLORATION CHALLENGE

ROBOTICS



Educator Guide

Follow the Engineering Process
to Complete a Challenge

NATIONAL
GEOGRAPHIC

NatGeoEd.org/NGX

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NATIONAL GEOGRAPHIC PRESENTS
ROBOTS 3D
PRESENTED BY LOCKHEED MARTIN

Visit www.NatGeoEd.org/NGX to find more NGX content and
www.NatGeoEd.org/Robots to find more robots content.

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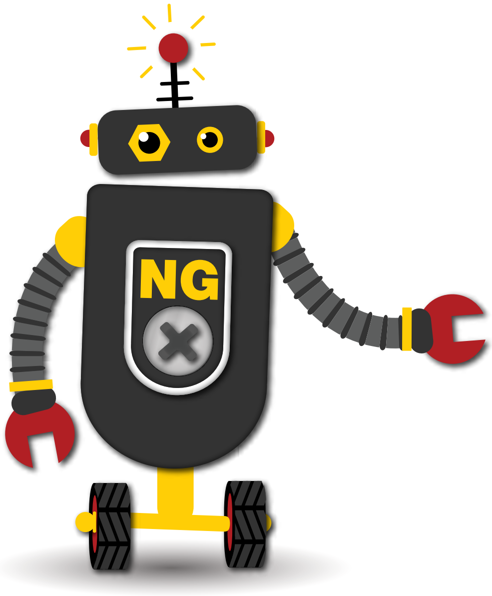


Dear Facilitators,

National Geographic invites you to challenge your students to be explorers by participating in the Engineering Exploration (NGX) Challenge. The NGX Challenge provides three distinct engineering challenges for students, each based on real-world challenges National Geographic explorers face in the field. This year's challenges focus on the use of robotic technology to accomplish tasks that people find too dull, dirty, or dangerous to do directly. Robots can do lots of things, but one thing many robots do is collect information about their environment. These robots use sensors, such as cameras or thermometers, to gather information about their environment. Then, the robots decide on an action to take based on the information. For a robot, collecting this information is really important when it comes to taking action and solving problems, big and small. Like a robot, students' solutions to the NGX Challenge must involve collecting information about their immediate environment and using that information to decide what action to take, the same way a robot might. The resulting action can be as big or small as students imagine, and should help solve the challenge of the students' choice.

In the first challenge, students design, build, and test a way to study a migrating animal using their own robot-like design. In the second challenge, students design, build, and test a way to collect real data about a place—close or far away—using their own robot-like design. In the third challenge, students design, build, and test a way to study an extreme place they'd like to explore but cannot or should not go. Students can choose to solve one, two, or even all three challenges.

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 educational or extra curricular program with a focus on or interest in promoting science, technology, engineering, and mathematics (STEM).

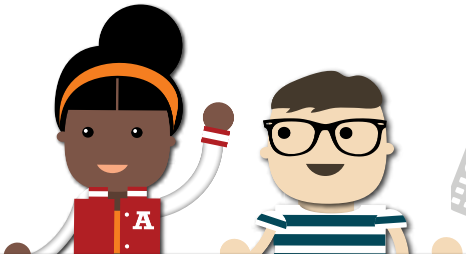
The challenges address the engineering design standards in the Next Generation Science Standards (NGSS) and, because they ask students to document each step of the engineering process, they provide an excellent way to address the Writing in Science and Technical Subjects standards from the Common Core Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects.

This educator guide provides all of the information you need to get your students started. The following pages include general tips on how to address the challenges for both older and younger students in a variety of settings, as well as specific tips and suggested materials lists for each challenge to help you get started. It also includes suggestions for warm-up activities, and information about a set of National Geographic robotics activities that provide valuable context for these challenges. Tips are also included on how to use the Engineering Process student workbook to integrate the engineering process into the challenge.

Robotics is an exciting topic for students to explore, and the NGX Challenge is an excellent way to motivate your students to become problem solvers and engineers. We look forward to the innovative solutions they will create!

Happy exploring!

National Geographic



Tips

General Tips for All Challenges

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. See the Warming Up and Preparing section of this guide for warm-up ideas.
- Build skills. Providing students with background information and skills related to robotic technology can help elevate their challenge solutions. Use the National Geographic activities listed in the Warming Up and Preparing section of this guide as general preparation for students before introducing the challenges or as tools for students to address specific areas, such as gears or circuits, they identify as part of their solution.
- Understand the role of robotic technology in challenge solutions. When discussing robotics, students may imagine humanoid robots. Help students expand their understanding of robotic technology using the information and ideas in the "What is Robotic Technology?" section of this guide.
- Students do not need to build a humanoid robot to complete the Engineering Exploration Challenge. Their solutions must be robot-like in that they must sense something about the environment and make a decision using that information. Create a list of sensors with students before beginning the challenge to spark ideas on different ways their solutions might collect information about their environments.
- Encourage students to be as specific as possible in developing their solutions. Have students pinpoint a specific task they would like their solution to accomplish.
- Reinforce the idea of failure as a step on the way to success. Remind students that, not only is it okay for their designs to fail, but also that failure is an important part of the engineering process. The emphasis should be on critical thinking, problem-solving, and the engineering process, rather than a perfect solution.
- Safety first. Always check students' designs to make sure they are safe to build before allowing students to move on to the building phase. During the building phase, make sure students are supervised. If they are using tools, they must know how to use them safely and be wearing 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 any problems with their designs. Instead, use questioning 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 materials by having students create a smaller prototype of their solution to test for proof of concept. This will prevent you from wasting larger or more expensive items in this early phase. Once students have proof of concept, you can procure the items they will need to build their actual solution. This will save both time and materials. National Geographic encourages the use of recycled or reusable materials in all solutions. Create your own robotics kit using the *ROBOTS 3D* Activity Kit Guide.
- 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. Creating 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 emphasize the collaborative nature of engineering. Collaboration enhances creative thinking by bringing in multiple viewpoints. Keep groups small enough that all students get to work hands-on. Groups of three to five work well.
- Peer review. If students are working on a challenge individually, plan some time for peer sharing and review at the design level and again during testing. Have students ask each other 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 in order to build the design themselves. Allow them ample time to revise their plan.
- As students are planning and designing, hold mini skills lessons on topics such as wiring a motor, using gears, and using simple machines. The National Geographic activities listed in the Warming Up and Preparing section of this guide are useful resources for such lessons.
- Younger students may find it easier to identify a focus for their challenge from familiar environments. For each challenge you are addressing, ask students to identify some places they have been to or animals they have seen that would fit the challenge.
- Help younger students break down the challenge by identifying specific tasks they need their solution to do. Look at them one at a time. For example, students need to include a sensing mechanism in their solution. Create a list of sensors. Additionally, students may need their solution to move to a location and pick something up. Have them first brainstorm ways for their solution to move (e.g., wheels), and then ways to pick something up (e.g., grasping, magnets).
- 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.
- Use the guiding questions provided in the Tips for Each Challenge section of this guide to help guide students' thinking as they plan their solution.
- Plan at least eight to ten hours for elementary students and five to seven hours for middle school students to complete each challenge, with outside 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 and additional time to gather any new materials.
- If working with mixed-age groups, pair a younger student with an older student, rather than separating age groups. Instruct older students to help guide younger students through the engineering process.

Tips for Older Students

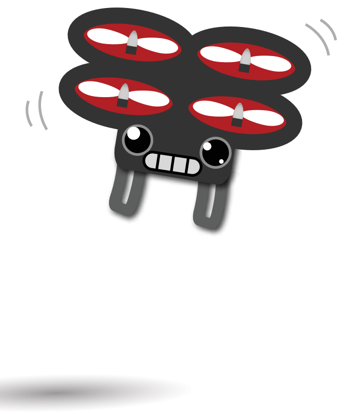
- Providing materials at the onset of the challenge may be limiting to older students. Instead, have them design their solutions and then provide you with a list of materials they will need. If they request materials that are too expensive or otherwise unavailable, have them propose alternatives. You can use the suggested materials lists to plan ahead for what you might need. However, if students struggle to generate ideas, provide them with some materials to explore and jump start 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 provide ample time for students to address problems and re-test. Plan at least twelve hours for high school students, plus additional time for gathering materials, for students to complete the challenge. More advanced solutions may require even more time. If possible, plan a block of time—three to four hours—for students to build, test, and re-engineer their prototype. Also plan for a follow-up session during which students can gather additional materials they may need.
- Older students may be interested in more sophisticated solutions requiring computer programming or more advanced building methods. Collaborate with the computer science and technology instructors in your school or community to assist any students who may want to pursue this direction. Local Maker programs may also be a resource for mentors and tools these students need.

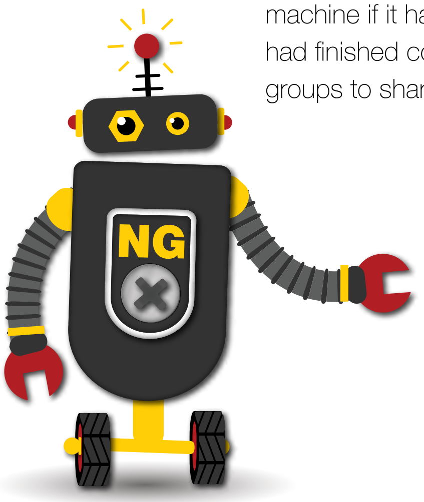
What is Robotic Technology?

When you mention robots, many students may initially imagine humanoid robots, which have human-like features such as faces, arms, and legs. However, most robots are not humanoid. Instead, robotic technology is usually designed so that its form matches its function. Robots that need to fly may resemble an insect, while those that need to travel over rough terrain may resemble small tanks. Robotic technology can be found anywhere from factories, in the form of crane-like arms that assemble parts, to cleaning our homes, in the form of robotic vacuums.

So what makes a machine a robot? To be considered robotic, a machine needs three parts: sensors, actuators, and a program. The sensors sense the world around the robot in some way. This might be a robotic vacuum sensing when it has hit a wall or robotic cameras sensing when there is movement nearby. Actuators enable movement, such as traveling over an area or lifting and moving an object. A program enables robots to act without direct input from humans. A program is what tells a robotic vacuum to change direction when its sensors indicate that it has hit an obstacle. For the purposes of this challenge, National Geographic is asking students to build robot-like solutions that meet two qualifications: solutions must sense something about the environment and make a decision based on that information. Solutions can be sophisticated or simple.

To complete these challenges, students need to design, create, and test a solution to solve a specific challenge. Robotic technology is different from the humanoid robots that many students will imagine. Before students begin working on their solutions, expand their thinking about robots with the following brief activities:





- As a class, brainstorm some ways people, animals, and robots sense the world around them. As students brainstorm, encourage them to adapt their ideas into simpler and more complex ones. For example, sensing movements could be as complex as a motion detector, or as simple as a trip wire. Then, have students brainstorm in small groups to come up with some ways the sensory information can result in action. Again, emphasize that i deas can be complex or simple—a motion detector being triggered might send a wireless signal to an alarm. A trip wire being triggered might cause a stack of cans attached to it to fall over. Allow small groups to share their ideas with the class. A good activity to use with younger students is Making "Sense" of Robot Sensors.

- Watch and discuss the ten-minute video SciShow: Robotics. As they watch, have students keep a list of the robotic technology they see or hear about in the video.

- Read and discuss the article "What is a Robot?" Then, have students categorize different machines as "robotic technology" or "not robotic technology." Have them justify each response based on evidence from the article. Be sure to use both examples and non-examples, for example, toaster, microwave, self-scanner at a grocery store, robotic vacuum, your car, automatic doors, and so on.

- Divide students into small groups and provide each group with a non-robotic machine. Ask groups to devise changes to that machine that would turn it into a robotic machine. For example, a microwave could become a robotic machine if it had a way to sense when the food inside it had finished cooking and automatically turn itself off. Allow groups to share their ideas with the class.

Facilitating the Challenge in a Variety of Environments

The NGX Challenge is a good fit for a variety of formal and informal education settings.

Classrooms

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 in Challenge 1 to integrate with life sciences. Focus on environmental data-gathering in Challenge 2 to integrate with the Earth sciences. Provide a tie to physical sciences by focusing on the mechanics of the solution, including gear systems, simple machines, or hydraulics. Emphasize circuits and electronics as part of a unit on electricity. Use the robotics activities described in the Warming Up and Preparing section of this guide to give students a deeper understanding of the science behind robotics.

Have students in your classroom work in teams to design, build, and test their solutions while using the engineering process. Encourage other classrooms to get involved in the challenge and then arrange for your students to share their final solutions with those students. Even if some solutions are unsuccessful, students will be able to discuss how they might modify solutions to make them successful. Be sure to emphasize the importance of failure during the challenge process. Seeing the different ways other students approached the same challenge will be a valuable learning tool for all.

Museums

Museums can help build enthusiasm for the NGX Challenge in a number of ways, as well as provide a place for participants to share their solutions. Put together a display of robotic technology. Host a kick-off party for the challenge and show the videos introducing each challenge. Depending on your institution's focus, you might also offer question and answer sessions with experts in related fields during the course of a challenge, hold skills workshops, conduct one or more of the robotics activities described in the Warming Up and Preparing section of this guide, or provide tips and assistance for research. If possible, hold workshop days for participants working on the challenge and provide workshop space and tools for participants to use as they build their solutions. If you do host a workshop day, be sure to provide the challenges to participants in advance, so they can do any research before they start building. At the end of a challenge, host an NGX Challenge expo and invite participants to bring in their solutions to share with one another. Consider asking participating schools to send representatives or open it up to the general public. If your institution is screening *ROBOTS 3D*, celebrate participants' accomplishments with a screening of the film following the expo. More ideas on how to work with *ROBOTS 3D* are featured in the Using the Challenge with *ROBOTS 3D* section on the next page.

Libraries

Libraries can also help build enthusiasm for the NGX Challenge, as well as provide support and a place for participants to share their solutions. Put together a display of books about robots and robotic technology, as well as books relating to the topic of each challenge. For example, gather books about animal migration for Challenge 1, books about special places for Challenge 2, and books about extreme environments for Challenge 3. Bookmark websites that participants might use to research these topics on library computers. Host a kick-off party for the challenge and show the videos introducing each challenge. Follow up with a research day, where librarians assist participants in researching topics related to the challenges. For younger participants, host a read-aloud session centered around robots. For older participants, invite an expert in robotics to give a presentation. If possible, partner with local Maker groups to host workshop days for participants working on the challenge and provide work space and tools for participants to use as they build their solutions. If you do host a workshop day, be sure to provide the challenges to participants in advance, so they can conduct any research before they start building. At the end of the challenge, host an NGX Challenge expo and invite participants to bring in their solutions to share with one another. Consider asking participating schools to send representatives or open it up to the general public. Celebrate students' accomplishments with a screening of *ROBOTS 3D* following the engineering expo.

Summer Camps

The NGX Challenge can be easily integrated into a summer camp, as a week-long focus or even just for a day. To use the challenges over the course of a week, begin by showing the videos introducing each challenge. Have campers brainstorm all the things they might need to know to solve one of the challenges. Each day, have campers do one or more of the warm-up activities and one of the robotics activities from the Warming Up and Preparing section of this guide. Use the Engineering Process Workbook as a guide for students to work on researching, developing, building, and testing their solution. If campers will work on the challenges in a single day, be sure to provide the challenges in advance and ask campers to research and brainstorm beforehand so they are ready to build.

Using the Challenge with *ROBOTS 3D*

The NGX Challenge complements the movie *ROBOTS 3D*. To combine them most effectively, introduce the challenges before screening the film. Discuss robotic technology, and give participants time to research and brainstorm before seeing the movie. Show the movie as part of the research phase of the challenge, and ask students to point out specific examples of robotic technology they see in the film. For example, ask students to point out when they see sensors, actuators, or examples of programming. Have them deconstruct the humanoid robots they see in the film, identifying the parts that make up the whole. Alternatively, show the movie at the end of the challenge as a celebration of a job well done. Locations playing the movie can be found at movies.nationalgeographic.com.

Warming up and Preparing

Quick Warm-ups

- Show students the video NG Live!: Robot vs. Tiger. Ask students to define what the explorer's problem was in the video and how he solved it. Ask: *Did he start completely from scratch to create his solution? What did he use?* Then challenge students to solve the problem of moving a penny (or paper clip, etc.) three feet without touching it using only supplies they can find in the classroom. Give students ten minutes to solve the problem.

- Use previous years' NGX Challenges to get students warmed up for this year's challenge. Divide students into small groups and assign each group a challenge from previous years. Give them thirty minutes to brainstorm and design solutions. Because this is just a warm-up, students don't necessarily need to build and test their solutions; a drawing or prototype will suffice. Allow time for groups to share their solutions with the class. If you ask groups to do the same challenge, be sure to discuss how they came up with different ways to solve the same problem.

- Set up stations for students to practice skills they may need to solve the problem. Station ideas include:
  - Tools station: Include small blocks of wood, safety goggles, a screwdriver, a hammer, nails, and screws. Allow students to practice with the hammer and screwdriver.
  - Circuit station: Include electrical tape, wiring, and a small motor, buzzer, or lightbulb. Have students design a circuit to light the bulb or activate the buzzer or motor. For support, see the activity Building Circuits.
  - Gears station: Have students experiment with gears using spools, pegs, rubber bands, and a peg board. Encourage students to experiment with different configurations of gears by asking them to place two pegs in the peg board and a spool on each peg. Have students connect the two spools with rubber bands in order to create a gear set model. Challenge students to set up gears so that one gear turns faster, more slowly, and in a different direction than the other gear. More scenarios for experimentation can be found in the Gearing Up with Robots activity.
  - Pneumatics/hydraulics station: Include syringes of different sizes, small plastic tubing, tape, and a small folded piece of cardboard (a cereal box will work well). Have students attach syringes to both ends of the tubing and experiment with making one syringe move by changing the position of the other one. Challenge them to use the syringes to open and close the folded cardboard. Have students add water to the syringes and observe any differences. The Exploring How Robots Move activity has additional information about using syringes to demonstrate hydraulics and pneumatics.
  - Pulley station: Include four pulleys, a small weight with a way to attach it to the pulley, rope, and something from which to hang the pulley. (A clamp stand works well, but in a pinch students can hold the pulleys.) Have students use different configurations of pulleys to lift the weight, noting which makes the weight easiest to lift. Some configurations include one fixed pulley, two fixed pulleys, one fixed and one moving pulley, and so on.

- To stimulate students' creative thinking, give them five-minute challenges, using simple materials. Some ideas include:
  - Devise a way to make a box change appearance and then change back without directly touching it. (Provide students with a small cardboard box, paper, markers, craft sticks, rubber bands, pipe cleaners, and tape.)
  - Build a bridge that will span an index card and hold as many pennies as possible. (Give students an index card for reference only, paper, a small amount of tape, and at least ten pennies.)
  - Devise a way to move marbles from one container to another container two feet away, without touching the marbles or the containers. (Provide students with straws, craft sticks, a small amount of tape, index cards, syringes, plastic tubing, a plastic spoon, and pipe cleaners.)
  - Find more ideas in the activity Simple Machine Challenge.

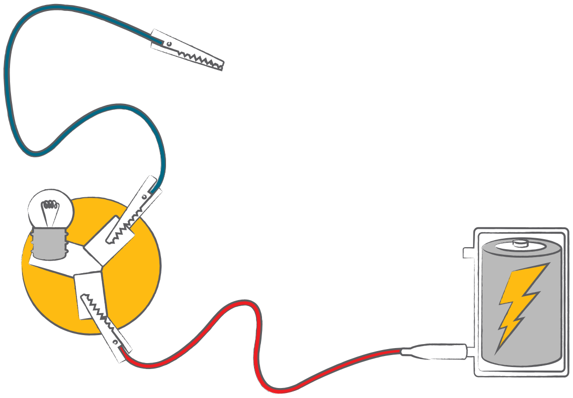
Activities

The National Geographic activities below can provide excellent background for the NGX Challenge. The full activities can be found online at NatGeoEd.org/Robots. Once you have selected the activities you want to use in your classroom, you can use the print button in the upper right corner of each activity to print the activity.

Electricity and Circuits

Circuits with Friends
Grades: 2-5 Duration: 20 minutes
Students explore the parts of a circuit by modeling, as a group, a "human" circuit.

Building Circuits
Grades: 4-8 Duration: 30 minutes
Students experiment with batteries, wires, bulbs, and switches to assemble series and parallel circuits and to test for conductivity in sample items.



Actuators, Mobility, and Sensors

Making "Sense" of Robot Sensors
Grades: 1-5 Duration: 20 minutes
Students discuss the importance of senses and experiment using echolocation as an example.

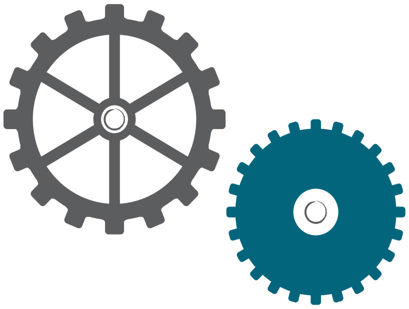
Exploring How Robots Move
Grades: 3-8 Duration: 35 minutes
Students experiment with pneumatics and hydraulics and apply these systems to produce movement.

Round and Round with Simple Motors
Grades: 6-12 Duration: 60 minutes
Students forge a hypothesis about how motors make things move, and then build a simple electric motor using wire, a magnet, and a D-cell battery to explore how motors convert electrical energy into mechanical energy.

Simple Machines and Gears

Simple Machine Challenge
Grades: 2-8 Duration: 50 minutes
Students are challenged, using everyday objects, to create simple machines to complete specific tasks.

Gearing Up with Robots
Grades: 3-8 Duration: 35 minutes
Students experiment with gear motion to understand how gears work to change the amount of force, speed, or direction of motion in machines.



Programming and Operation

How to Train Your Robot
Grades: 2-8 Duration: 35 minutes
Students apply logic and sequencing skills to write instructions, called an algorithm, for a student to complete a simple task acting as a robot.

Tips for Each Challenge

CHALLENGE 1

Animal Migrations

How do you study an animal that can't sit still?

Challenge 1 asks students to think about how to use robotic technology to study animals as they migrate. Since this challenge is open-ended, students can select any migrating animal(s) as their focus. Students need to think about the behavior of their selected animal, the geography of where their animal travels, if they want their solution to stay in one place and wait for the animals or to travel alongside the animals, and what kind of sensors to use. They also need to think about what kind of data they are collecting, by deciding why they want to study that particular animal.

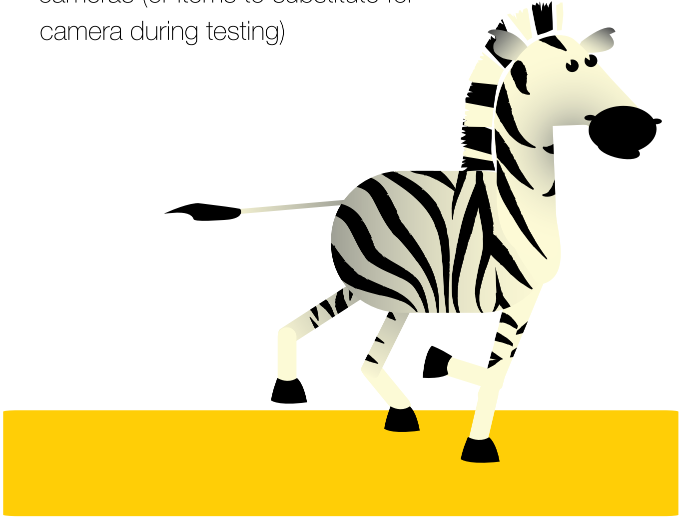
Spotlight on National Geographic Explorers

Dereck and Beverly Joubert, award-winning filmmakers and Explorers-In-Residence, have made it their mission to protect and conserve big cats in Africa. They utilize photography and film to bring the message of conservation to their audiences. The Jouberts use camera traps to take photographs of lions when they cannot be there themselves. These camera traps are often stationary and use motion sensors to take photographs when animals are close by.

Other National Geographic Explorers who study animal migration include Cagan Hakki Sekercioglu and Greg Marshall. Sekercioglu researches the causes and effects of bird extinctions around the world. Marshall is a marine biologist and filmmaker who developed the Crittercam. The Crittercam allows researchers to film animals without disturbing their natural behaviors. Crittercams travel with the animals by harmlessly attaching to them. They submit footage and/or location data back via satellite.

Suggested Starting Materials

- a variety of recyclable materials (soda bottles, cans, cardboard, etc.)
- pulleys
- string
- rubber bands
- D-cell batteries
- wheels
- dowels
- brads
- plastic tubing
- paper clips
- duct tape
- syringes
- straws
- cameras (or items to substitute for camera during testing)



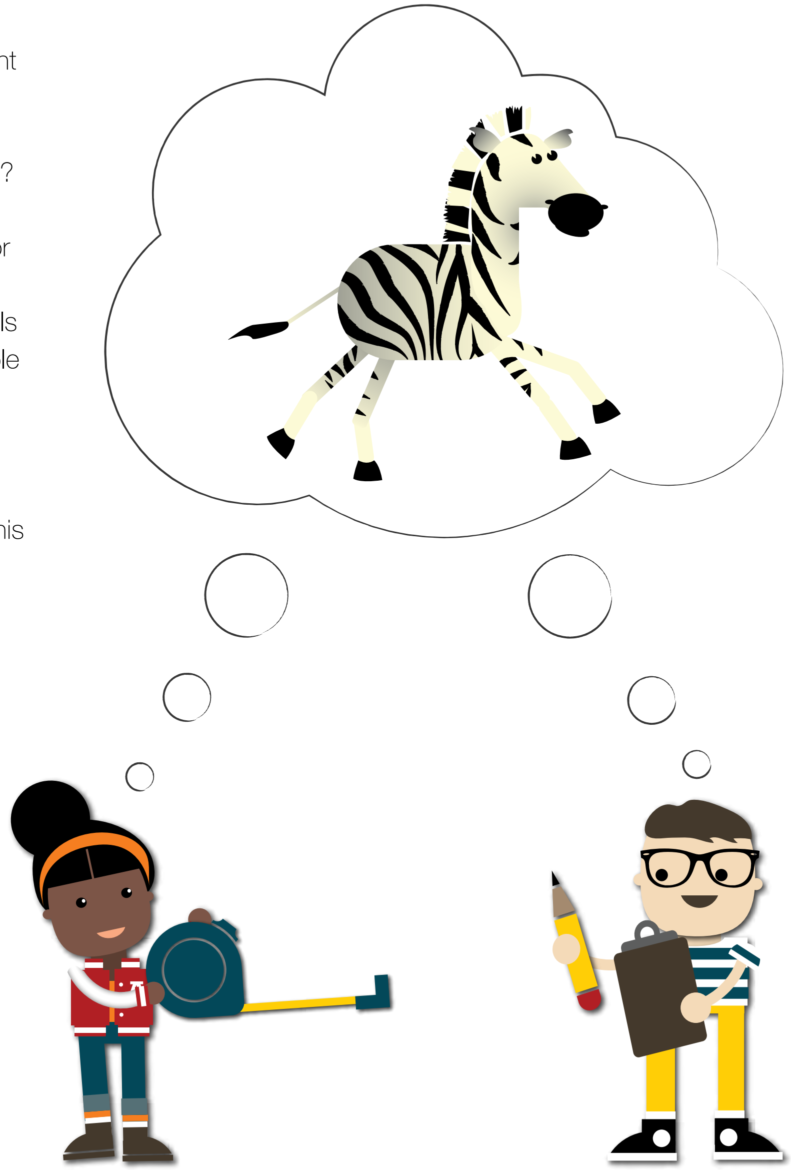
Tips

- To help students think through solving this challenge, use the following prompts:
    - What are some animals that migrate? Why do researchers study these animals' migration?
    - What animal will you study and why? What kind of information (data) do you want to collect?
    - Why is studying this animal's migration important?
    - How does your animal move? Does it fly, swim, or run? Where does it go? How will these things affect your solution?
    - What kind of sensor best fits your needs? What will your solution do based on the sensory information it collects?
    - What are the environmental features that you must consider with your design? How will the environment affect your robotic technology?
    - How will you detect the animals or animal evidence? Animals act differently when humans are around. Why will your robotic technology be undetectable or unimportant to the animals?
    - How will your robotic technology monitor the animals along their travels? Will it follow them? Or will multiple robots be stationed along the migration route?
    - Why is it better for robotic technology to do this, rather than a person?
- If students need help selecting a migrating animal, use this list to get them started:
    - Arctic terns
    - Caribou
    - Christmas crabs
    - Golden eagles
    - Humpback whales
    - Jellies
    - Loggerhead turtles
    - Monarch butterflies
    - Red crabs
    - Rocky mountain bighorn sheep
    - Salmon
    - Sperm whales
    - Wildebeest
    - Whooping cranes

You can also find more information about animal migration by visiting National Geographic's Great Migrations collection.

- If students' initial designs are not practical to test in the classroom, have them focus on one aspect that is. For example, if students designed a mobile video recorder that is meant to follow an animal as it migrates, they might focus on testing how that camera would move.

- Students may need to simulate their selected animal in order to test their solutions. Have them incorporate real data about the animal (weight, speed, etc.) into their testing.



CHALLENGE 2

How do you prove that a place is special?

Challenge 2 asks students to think about how to tell the story of a place that students think is special. This place could be somewhere far away or somewhere nearby. Because students need to be able to show why this place is special, this challenge asks students to collect consistent data over a period of time. A day is a good testing unit. Students will need to think about the geography or cultural history of a place and how to best communicate what is unique. They also need to think about what kind of data they are collecting to tell that story, and what kind of sensor they can use to collect that data.

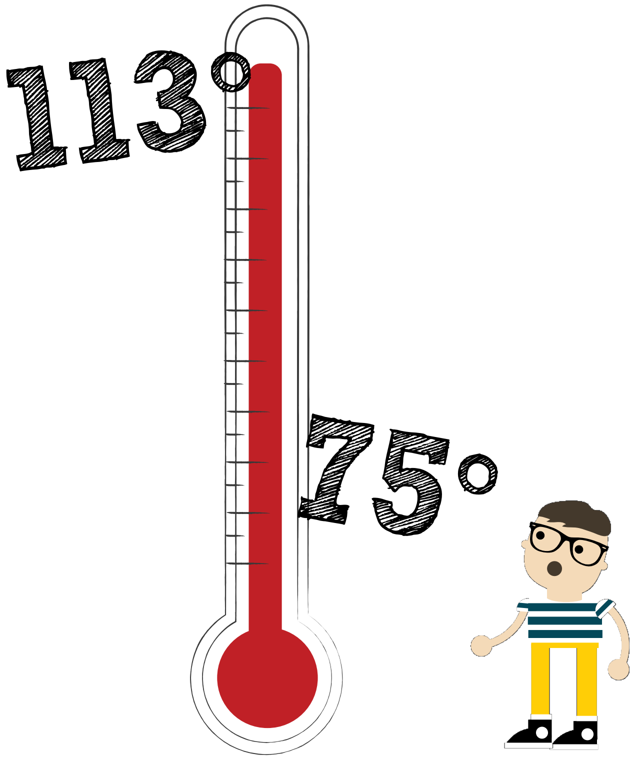
Spotlight on National Geographic Explorers

Explorers Shah Selbe, Steve Boyes, Gregg Treinish, and Jer Thorpe are going on an expedition to the remote Okavanga delta region, a secluded and dangerous area in Botswana that is rich with wildlife like elephants and hippos. The area is currently under threat from mining practices in Angola, north of Botswana. No baseline data exists for the area, which means it is hard to tell if the mining is causing environmental damage. In order to protect the area and the animals that live there, they need to create a baseline for the area by collecting environmental data over a large area for a long period of time. They have created sensors that monitor water quality, like pH.

Other National Geographic Explorers who collect environmental data include Erin Pettit, Bethany Ehlmann, and Jim Belog. Pettit explores glaciers to better understand and predict changing climate and rising seas. Ehlmann uses a robotic rover to study the planet Mars, collecting soil and rock samples and other data. Belog takes photographs over a period of time to document the world's melting glaciers.

Suggested Starting Materials

- a variety of recyclable materials (soda bottles, cans, cardboard, etc.)
- gears
- pulleys
- string
- rubber bands
- D-cell batteries
- small motors
- dowels
- brads
- plastic tubing
- syringes
- straws
- thermometers or other sensors
- pH paper
- index cards
- duct tape



Tips

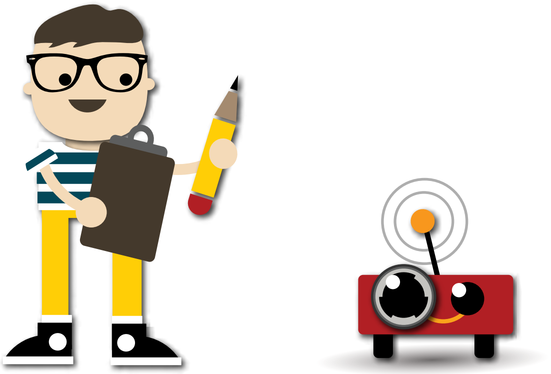
- To help students think through solving this challenge, use the following prompts:
    - What are some places you think are special? Why? What makes a place special?
    - What would you say to someone who has never been to this special place to convince them it is special?
    - What type of data are you collecting to support your argument that this place is special? Environmental, photographic?
    - Where are you going to go to collect this data? Locate your place on a map. The place you study must be real, not imaginary.
    - What kind of sensor best fits your needs? What will your solution do based on the sensory information it collects?
    - What are the environmental features that you must consider with your design? How will the environment affect your robotic technology?
    - Why is it better for robotic technology to do this, rather than a person?

- Brainstorm different types of environmental data with students. Environmental data can include information about weather, air quality, water quality, soil content, and more. Some environmental sensors that may be found on robots include:
    - Light sensors—to detect light
    - Cameras—to gather visual information
    - Sound sensors—to detect sound
    - Temperature sensors—to detect fluctuations in temperature
    - Contact sensors—to avoid obstacles
    - Proximity/distance sensors—to detect distance of objects in relation to the robot
    - Pressure sensors—to sense the degree of pressure applied to an object being manipulated

- While students may identify a variety of environmental data to collect, they can focus on just one type of data for the purposes of this challenge.

- Instead of data that requires readings, students' solutions can include collecting environmental samples, such as soil or rocks. This might be a good option for younger students, as the solution could rely more on simple mechanics and less on electronics.

- To help students identify a special place to focus on, brainstorm reasons a place might be special. This could include: the natural resources found there, such as rainforests, nature preserves, or habitats for a specific animal; geological features, such as special caves, unusual landforms, or vast canyons; cultural resources, such as the Sphinx of Egypt, India's Taj Mahal, or American Indian cliff dwellings; or places of personal significance, such as a favorite park or the schoolyard. Looking at UNESCO World Heritage Sites might give students some inspiration.



CHALLENGE 3

How do you explore an extreme place that you cannot or should not go?

Challenge 3 asks students to find a way to visit and collect data from a dangerous or extreme environment that isn't safe for humans to visit directly. Exploring extreme environments like an active volcano, the deepest and darkest parts of the ocean, and the depths of outer space are some situations where National Geographic Explorers find themselves engaged in "dangerous" tasks. Explorers can learn about dangerous or inaccessible places by deploying robotic technology in their stead. In this challenge, students must consider the environment they want to explore and what about it makes it uninhabitable for humans. Their solutions will need to be able to withstand these harsh conditions, collect information about the environment, and somehow return that data to the student.

Spotlight on National Geographic Explorers

Dr. Katy Croff Bell is an ocean explorer, using deep-sea technology to explore what lies at the depths of the ocean, where it is too dangerous for humans to go themselves. Bell is the chief scientist of the Nautilus Exploration Program, which uses remotely operated vehicles and other technology to study archaeologic and geological points of interest in the ocean and transmit images back to students and researchers on land.

Other National Geographic Explorers who explore dangerous environments are Carsten Peter, Emma Stokes, and Corey Jaskolski. Peter is a photographer who comes up with ways to take photographs in some of the most extreme environments on Earth. He has photographed in toxic caves, deep ice shafts, and even inside active volcanoes. Stokes discovered a population of rare gorillas when she and her team were the first to explore a dangerous area of the Congo. Jaskolski devised cameras and other equipment that could travel though long and complicated cave systems in Mexico called cenotes.

Suggested Starting Materials

- a variety of recyclable materials (soda bottles, cans, cardboard, etc.)
- pulleys
- string
- rubber bands
- duct tape
- D-cell batteries
- small motors
- dowels
- brads
- plastic tubing
- syringes
- straws
- index cards
- thermometers or other sensors
- foam or other insulating materials
- small flashlights or book lights

Tips

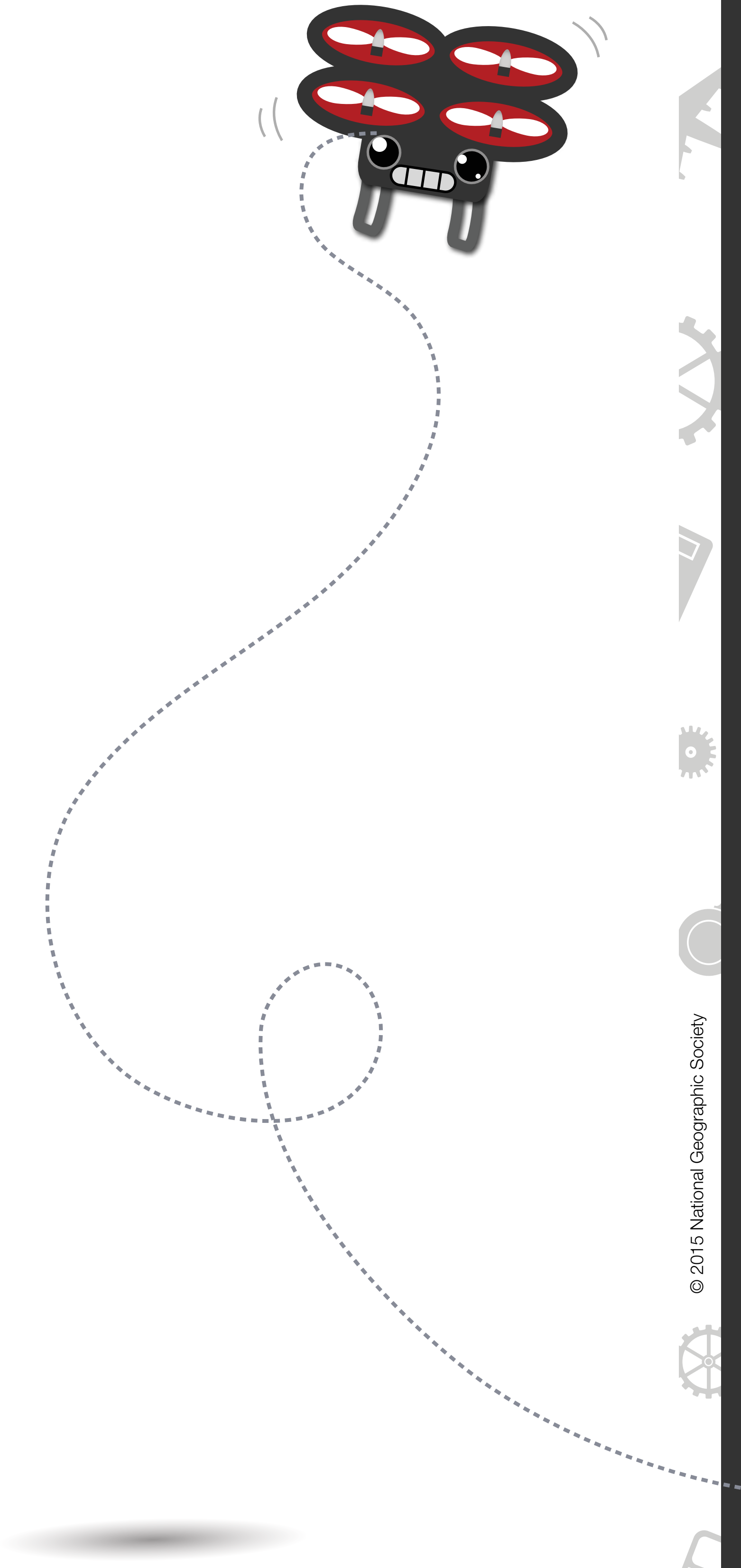
- To help students think through solving this challenge, use the following prompts:
    - What are some types of extreme environments or environments that are dangerous to humans?
    - What extreme environment are you interested in studying and why?
    - What data are you trying to gather?
    - What's it like there? Why is it not safe for humans to go there? How will the environment affect your solution? How will you protect your solution from these conditions?
    - Where will you need to go? Locate your place on a map. The place you study must be real, not imaginary. Describe the environmental features that you must consider with your design.
    - What kind of sensor best fits your needs? What will your solution do based on the sensory information it collects?
    - How will you get the data back from the environment? Will your solution travel back or send the data back electronically?
    - Why is it better for robotic technology to do this, rather than a person?

- Brainstorm some extreme places where it would not be safe for people to go unaided. Some examples include: places that are extremely cold, like parts of Antarctica; places where the pressure is too great, such as the bottom of the ocean; places that are too hot, such as the inside of a volcano; and places that lack enough oxygen, such as another planet.

- One suggestion for testing is to have students identify the specific danger posed to humans by this location and test how their technology stands up to that hazard.

- For safety reasons, some hazards will need to be adjusted for testing purposes. For example, students should not and could not test with materials as hot as the inside of a volcano, but they can test in hot water.

- Students may choose to focus on testing how they will get information back from the dangerous place. This could involve electronic solutions or purely mechanical solutions.



Using the Engineering Process Workbook

The following pages include the student workbook for the NGX Challenge with annotations for the facilitator. 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.

Tips

- 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 worksheet. Have students record their work in a notebook.
- The Engineering Process workbook and Engineering Process worksheet can be downloaded at NatGeoEd.org/NGX.

This educator guide and NGX Challenge developed by National Geographic Education and Children's Media.

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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.
- After students have conducted initial research, have them revisit their definition of the problem. Have them redefine the problem as it addresses the specific application they have chosen as their focus.

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

NatGeo

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.
- As students research, have them narrow down the topic until they have a specific application on which their solution can focus. For example, by the end of the research phase, they might have a specific animal, location, or task they will build their solution around.
- 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' solution proposals should provide context by including specific information about where and how their solution would be applied. For example, they might say that their solution will be designed to operate in a certain location or be used with specific animals.
- 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.

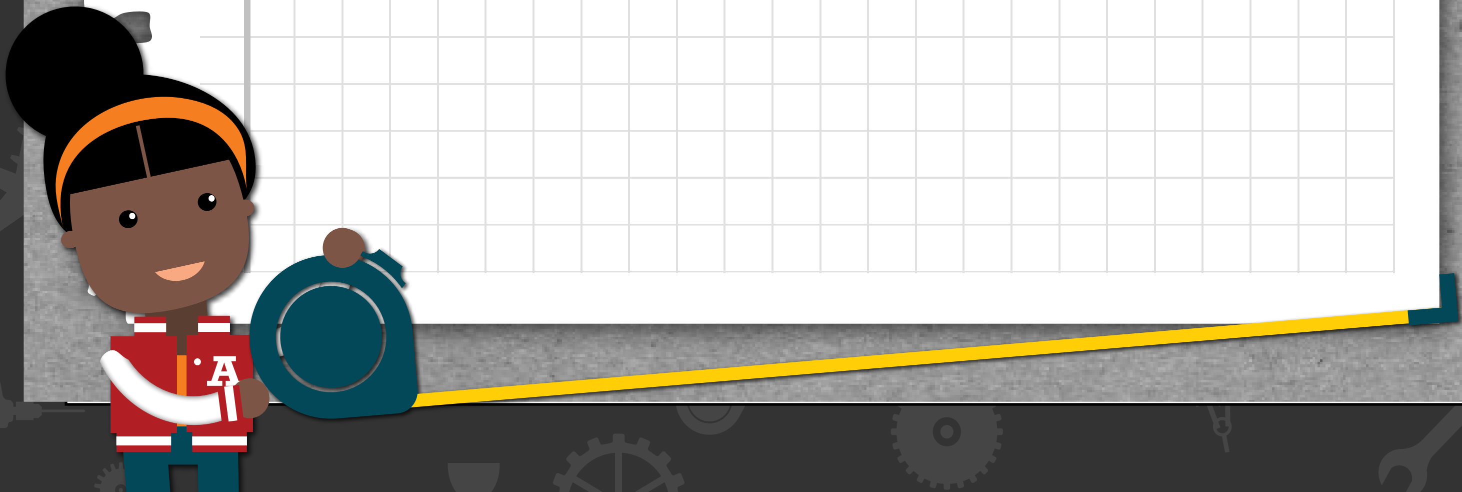
How will you test your solution to see if it works?

- 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.



DESIGN

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?

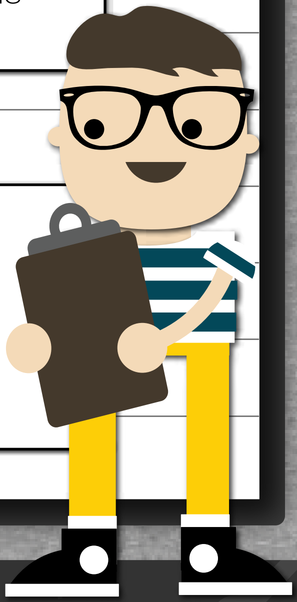
- Students may need to revise tables or charts they created in the planning phase after their first test.
- Check in with students as they are testing to make sure they are recording the information they will need going forward. As students improve their designs, they can use this data to track improvements.

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?

REFLECT