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Introduction

Challenges

Challenges vs. Lessons

The activities in this book are referred to as challenges, not lessons. They are quite different from traditional science lessons that tell students what to do and how to do it. The goal of these challenges is for students to experience phenomena for themselves, which requires a bit of letting go on the part of the teacher. Instead of lecturing or demonstrating, we are putting materials into the hands of students, setting them up for success and turning them loose to discover new concepts. Teachers are facilitators, laying out the challenge for students, scaffolding when necessary, providing guidance and checking in with groups in order to offer encouragement, advice, correction and support.

Students CAN meet the challenge!

Once students understand how the challenges work, they really dive into them. Students become fully engaged in working together on their own terms, manipulating materials, and solving a compelling problem or answering an intriguing question, with their hands and minds occupied and on task. And these challenges are not conducive to silence – a low buzz of purposeful conversation indicates that students are actively engaged. Your biggest problem may be getting them to wrap things up!

Keep in mind that we, as teachers, have to change our approach, too. We tend to want to know what the end product of a challenge should be – a finished product that the students can take home. But inquiry-based lessons in engineering design and the scientific process will naturally go in whatever direction students take them. Give students just enough information and scaffolding, and they will surprise you!

* Two Kinds of Challenges *

The challenges in this book provide just the right amount of structure and scaffolding to set students up for success but not so much as to stifle creativity and productive struggle. Each challenge is designed for students to gain experience in either the engineering design process or scientific inquiry.

- In the ***engineering challenges***, students create a solution to a problem and evaluate the effectiveness of their solutions. They learn how to use the engineering design process – *ask, imagine, plan, build (create), test, improve* – in order to arrive at the best solution that they can under the *constraints of the challenge*. The challenges introduce students to working with constraints (the rules and restrictions of a challenge) and criteria for success (the goals they are trying to accomplish). Students must think creatively, meaning that their solutions will (and should) vary widely; there are no "right" answers. Solutions are evaluated by the class based on how well the given problem is solved.

- For ***scientific inquiry challenges***, scaffolding is provided to give students developmentally appropriate experience in exploring questions, testing hypotheses, recording data and evaluating evidence. Students will work with *variables* instead of *constraints* in these challenges, learning basic procedures such as observing and recording what they see and hear. The teacher leads the class in organising and comparing data in order to evaluate evidence and reach conclusions.

Meeting the Challenges

* Productive Struggle *

Inquiry challenges give students a certain amount of freedom, but they should not be free-for-alls. These types of challenges can be overwhelming to students if the students aren't provided with enough structure. When you begin these types of inquiry-based activities, you will most likely encounter a lot of "I can't do it!" and "Can you help me?" Outside of actual physical incapability (many primary students really have trouble blowing up balloons and tying knots), encourage students to help one another before coming to you. Freedom may be new to some students, and they may be unsure about how to proceed. But, give too much direction, and students won't really internalise the concepts.

Prompt students with the constraints or goals of the challenge, and if they really are stuck, ask leading questions and offer a few choices of next steps they can take.

For example, you might say, "I see that your marble isn't making it through that tunnel you built". Then, follow up with questions, such as:

- Where do you think the marble is getting stuck?
- How could you change the tunnel to make it wider?
- Could you try a different material?

Once they get the hang of it, most students will stop asking for help and run full speed ahead into each challenge.

* Collaboration *

Collaboration is a big part of 21st-century learning and STEM (science, technology, engineering, mathematics), and cooperative skills are foundational in the primary years, but not all students work well together. Flexible grouping is important, as is student choice. If a student insists on working alone, that's perfectly acceptable, as long as they participate in a debrief with the class. You will find that even those lone wolves, once they see how much fun the other students are having, will most likely choose to work with others at some point. And if they don't, remember – Einstein and Tesla usually worked alone.

Students at this age work best in pairs, so start with groups of two and work up to groups of three or four. When pairing students or placing them in small groups, allowing them to choose with whom they want to work is often the best option, especially during the first few challenges. The activities are engaging enough that hijinks are rare; they are too busy to cause trouble.

As students get used to the procedures, you can mix it up and still offer student choice by specifying that everyone must work with someone they haven't worked with before. But always keep an eye on things – forcing students to work with others who make them uncomfortable is counterproductive because social interaction takes their focus off the challenges.

Cooperation at the planning stage of a challenge can be tough at this age. Students can find it difficult to let go of their own ideas, so they need to practise listening to, comparing and evaluating competing ideas based on their merits. Encourage listening, and teach ways to compromise, such as combining ideas or trying two different ideas to see which provides the best results.

* Copying Allowed *

Let students know that, because there are no right answers, copying is allowed! If a group is struggling with a task, one strategy they can employ is to observe the work of others. If students see someone else's great idea, encourage them to use it … with a twist or in a new way to make it their own. Even if they're really stuck and choose to copy another group exactly, they will still have their own experiences. Of course, if a particular student or group copies others in every activity, intervention is warranted.

* FAILURE Is a Step Along the Way*

Talk with students about the word *fail* and what it means in science and engineering. Failure is not the end of an experiment or a project – it is merely a step along the way. When students are asked to make predictions about what will happen in an experiment, be sure to let them know that it does not matter whether their predictions match what happens. Scientists are wrong in their predictions much of the time – it's part of conducting experiments.

Every failure provides an opportunity for improvement. Scientists and engineers look at why they think something happened and how they can fix or improve it. Then, they try again and again and again.

You might share with students that once on the *MythBusters* TV show, they tested whether elephants were afraid of mice (look it up online – the video is great!). They were absolutely sure that this was just a silly tale – why in the world would a giant elephant be afraid of a little mouse? But lo and behold, the elephants cautiously avoided the mice every time. Were the researchers upset that their prediction did not match the outcome? No! They were astonished and thrilled. *MythBusters*' Adam Savage summed it up: "I'm always pleased to be completely wrong".

* Making Connections *

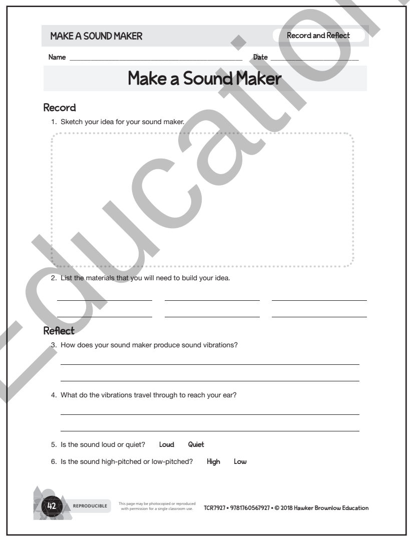
We want students to understand why things happen, but instead of telling them, we want them to discover for themselves. At the end of each challenge, bring the class together for a wrap-up session to debrief and analyse their results. This is important – this is where students make connections and internalise scientific processes and engineering concepts. Students will share and compare their ideas, experiences, data, constructions and most importantly, evidence.

Early primary students are just beginning to learn the difference between opinion and fact, and the key word to help them do that at this level is *because*. When a student makes a claim (*The eraser is the best projectile*), have them add the word *because* at the end and add their evidence (*The eraser is the best projectile because it went further than the pompoms and marshmallows*).

Teach students that evidence is what they observe (use their senses to perceive), not what they think or feel. By looking at data and concrete evidence, students build the ability to discern evidence-based fact from opinion. Bringing the whole class together to share data and observations and analyse outcomes lets us lead students toward discovery and understanding at their level and in their words. They will grasp and remember concepts much better when it comes from them instead of from us.

* Recording *

Scientists and engineers do a lot of writing to turn data into information. Every step of the scientific process is recorded so that other scientists in other places and at other times can replicate experiments. Engineers write procedures, reports, funding requests and more. STEM professionals write not only to communicate with others, but also to clarify their thinking, to explore new ideas and to come to conclusions.


MAKE A SOUND MAKER — Record and Reflect

Name ______ Date ______

Make a Sound Maker

Record

1. Sketch your idea for your sound maker.

2. List the materials that you will need to build your idea.

Reflect

3. How does your sound maker produce sound vibrations?

4. What do the vibrations travel through to reach your ear?

5. Is the sound loud or quiet? Loud Quiet

6. Is the sound high-pitched or low-pitched? High Low

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Throughout the challenges in this book, students will be recording their ideas, procedures and data. In some cases, they will answer questions that help lead them through an investigation or set them up for success in a challenge. At other times, they will record data as they collect it, and then analyse it to arrive at a conclusion or a result. And in engineering challenges, they will plan and list materials, sketch and evaluate. At the end of each challenge, students will reflect on their experience by answering a few questions to pull everything together.

Both speaking and writing give students an opportunity to articulate their thinking. As they work on a challenge, they discuss what's going on with other students (yes, even students working alone often have discussions with other students). These discussions allow students to work out their thoughts and observations, which makes writing easier. This is particularly helpful for English language learners who practise vocabulary and sentence structure as a natural part of their challenge-work time. Encourage students to use their natural language during challenges to communicate their ideas, even if grammar isn't perfect. The same goes for writing – don't worry so much about spelling and punctuation – focus on the ideas. The focus of students' writing should be communication, so scaffold as necessary:

- Write academic vocabulary on the board so that students can copy the spelling.
- Provide sentence frames.
- If necessary, allow students to dictate to an adult or student helper – often students' thinking skills are too fast for their writing skills.

Drawing is also a big part of recording in these challenges. (Visual and symbolic representations such as diagrams, blueprints, technical drawings, schematics and models are integral parts of science and engineering.) Sketching can help students to get their ideas on paper quickly and can force them to think through the relationships of the parts to one another and to the whole. Drawings are similarly great for assessment, as you can get an indication of how well students understood the challenge concepts by how the concepts are represented.

* Assessment *

Check for understanding in each challenge by means of formative assessment. This will give you a coherent picture of what students know and can do. To help you formatively assess students' understanding of the ideas, concepts and practices during each challenge, examine the following evidence:

- Observe students during work time and take notes during these observations.
- Listen closely during class sharing and discussions.
- Review the *Record and Reflect* pages in order to check data collection, student opinions and observations, and drawings at the end of each challenge.

These formative assessments provide multiple sources of evidence to guide you in making inferences about what students know and are able to do and also point toward the next steps in instruction.

Me and My Shadow

Objectives

- Students will learn about how shadows are made by participating in simple, hands-on demonstrations.
- Students will then investigate how their shadows change as the sun moves during the day.
- Students will be exposed to some academic vocabulary that is used in scientific investigation.

Time Frame

- The Introduction and Mini Challenge can be completed in one class session of about 20 minutes.
  Note: Do the Mini Challenge and the Main Challenge on separate days.
- The Main Challenge should be completed in two 30-minute segments, one in the morning and one in the afternoon on a sunny day.

Vocabulary

analyse	observe	record
evidence	opposite	shadow
light	predict	

Introduction

Materials

- torch
- small toy or stuffed animal

Setup

1. Arrange the torch and stuffed animal in an area for all students to view.
2. Have chart paper or a board nearby in order to add vocabulary and other important words as needed.

Mini Challenge

Materials

- A4 paper or other blank paper
- torches for each pair or group
- pencils
- small plastic toy, block or animal

Setup

1. Collect torches for each pair or small group.
2. Collect an assortment of small, plastic toy animals or other small, opaque objects for students to use in casting shadows.
3. If appropriate, prepare a tray that has torches, paper, pencils and small toys or stuffed animals for each group area.

Main Challenge

Materials

- *Me and My Shadow* (page 22)
- clipboards or other portable writing surfaces
- coloured chalk (suitable for drawing on concrete)
- pencils and coloured pencils

Setup

- Locate a space outdoors in full sun where students can trace their own shadows on the ground in chalk both in the morning and later in the day.
- The space should be away from buildings and trees so that the shadows don't overtake the workspace as the day goes on.

INTRODUCTION

1. Tell students that in this challenge, they will be learning about **shadows**.
2. Ask students to talk with a partner about what a shadow is and how a shadow is made.
3. Have some volunteers share their ideas about shadows.

✏ Write the word *shadow* on the board.

4. Hold up a small toy animal and a torch, and ask how you could use these to make a shadow. After some discussion, place the toy on the table and shine the torch at it to create a shadow.
5. Ask students to **observe** (*look carefully and notice things*) the shadow and describe it.
   - Is it short or long?
   - Is it wide or narrow?
   - What colour is the shadow?

✏ Write the word *observe* and its definition on the board.

Explain the Science

Lead students to understand that **light** travels in straight lines. If a solid object gets in the way, it stops the light rays from travelling through it, forming a dark area (shadow) on the other side.

6. Review what things are needed to make a shadow, and add them to the board if appropriate.

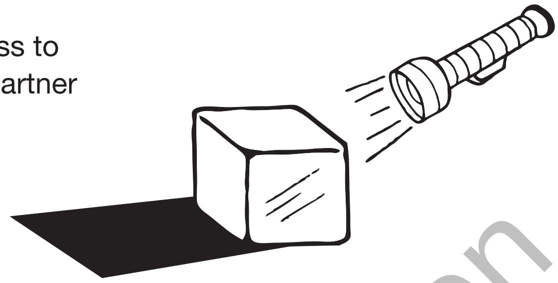
To make a shadow, you need:

✔ light

✔ an object to cast the shadow

✔ a surface for the shadow to fall on

Making Shadows



1. Have two student volunteers make shadows for the class to observe. Ask students to observe and discuss with a partner how each shadow is different.
   (*This one is longer; That one is on the other side.*)

2. Hold the torch to one side of an object, creating a shadow on the opposite side. Ask:

   – How can I make the shadow move to the other side?
   (*Move the torch to the other side.*)

3. Demonstrate by moving the torch and having students point out the new location of the shadow.

4. Introduce the word **opposite**. Say, "The light and the shadow are on opposite sides of the (____________)."
   object

5. Have students repeat the following phrase, and add it to the board if appropriate:

The light and the shadow are on opposite sides of the (____________).
object