DESIGN squad Global

CLUB

SIX-WEEK GUIDE

INVENTING GREEN

AN ENGINEERING AND INVENTION CLUB

Celebrate engineering, cross-cultural understanding—and have fun!

PBS KIDS WGBH The Lemelson Foundation improving lives through invention NCEES advancing licensure for engineers and surveyors UL INNOVATIVE EDUCATION AWARD

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Have you led a Design Squad Global club before and know the basics of getting your club launched? If so, you may want to jump to the new activities, which start on page 35.

There is new information here on talking with kids about environmental sustainability, a Master Materials List, and session descriptions.

DSG CLUB SESSIONS

SESSION 1
GETTING STARTED PAGE 35

Video: *Welcome to DSG!*

Meet your club members and talk about solving real-world problems.

Do the Warm-up Activity: A Very Big Brainstorm!

Learn about your partner club. Who are they and where are they from?

Tell your partner club about yourselves and ask them questions.

Handout: *World Map*

Handout: *DSG Membership Cards*

Form: *Partner Club Exchange*

Form: (optional) *Assessment*

SESSION 2
THE FLIGHT TEST CHALLENGE PAGE 49

Complete the first engineering and invention challenge: design an airplane that saves fuel!

Handout: *Designer's Notebook—Airplanes*

Poster: *The Design Process*

SESSION 3
THE SNEAKER CHALLENGE PAGE 62

Hear what your partner club sent about themselves!

Design sneakers that do not harm the environment when created or thrown away.

Handout: *Designer's Notebook—Sneakers*

SESSION 4
THE LIGHT PIPE CHALLENGE PAGE 72

Hear the answers to your questions about your partner club.

Design a way to bring sunlight into the prototype of a building!

Handout: *Designer's Notebook—Light Pipes*

SESSION 5

THE WIND POWER STATION CHALLENGE PAGE 84

Design a machine that can use wind energy to accomplish a task, such as lifting a weight or spinning a pencil to make a drawing!

Send your partner club what you have designed.

Handout: *Designer's Notebook—Wind Turbines*

Form: *Share Solutions*

SESSION 6

PARTNER EXCHANGE PARTY PAGE 97

Celebrate all you have built and the connections you have made with a party!

Handout: *Certificate of Achievement*

BONUS ACTIVITIES

BONUS ACTIVITY 1

THE GEARS CHALLENGE PAGE 103

Add gears to your wind turbine from Session 5. Turn the turbine into a machine that increases force to lift a heavier object.

BONUS ACTIVITY 2

THE TABLEWARE-TO-GO CHALLENGE PAGE 115

Invent a device, carrier, or system for taking along reusable spoons, forks, knives, and chopsticks.

INTRODUCTION

CLUB BASICS

About the Club

Design Squad Global club connects 10- to 13-year-olds in out-of-school programs around the world. Club leaders will introduce kids to engineering and invention activities focused on environmental sustainability. You will guide club members through the design process. These are the steps that engineers, inventors, and other creative people use to come up with solutions.

You will also give kids a special opportunity: the chance to work with a partner club from another country! This experience helps them develop "global competence"—an openness to sharing, communicating, and learning from kids in another part of the world.

HOW DO I GET MATCHED WITH ANOTHER CLUB?

You will be paired with a partner club from another country. Then, you and your partner club will run your clubs during the same period—you will do the same session during the same week.

HERE IS HOW IT WORKS:

1 Sign up at **pbskids.org/designsquad/global**.
2 Get matched with a club in another country.
3 Take the DSG Leader Training.
5 Get to know your partner club leader.
7 Lead your club!

Here is what happens during the club:

- You will introduce environmental sustainability and the design process through hands-on engineering and invention activities.
- In each session, kids use what they learned in the previous session.
- Your partner club will do the same activities.
- Partner clubs will get to know each other—share information about themselves, their countries, and the club activities they have completed.
- In the last session, there's a party. You will watch your partner club's video presentations about their engineering projects. And they will watch yours!

What Kids Will Learn from the Club

CREATIVE PROBLEM-SOLVING

Kids will

- use their imaginations and problem-solving skills to create unique designs.
- develop confidence in their own creativity and analytical skills.
- learn to consider many solutions rather than try to find one "right answer."
- discover how teamwork helps solve problems.

THE DESIGN PROCESS

They will

- use a series of steps to think through a problem. The design process is a method used by engineers, inventors, and other creative people.
- discover that the design process can help them solve many kinds of problems, not just engineering and invention ones.
- learn to think deeply about the first step of the design process: "Define the Need." Engineers and inventors think of effective solutions when they truly think about the needs of the people and places they are designing for.

ENVIRONMENTAL SUSTAINABILITY

They will

- discuss environmental issues that affect their communities and the world.
- brainstorm solutions that could help people with things such as lack of food, clean water, renewable energy, affordable energy, and ocean and land pollution.
- learn to design *sustainable* inventions—things made today that will not hurt the environment tomorrow.

GLOBAL COMPETENCE

They will

- develop "global competence"—the ability to communicate and collaborate with people from different backgrounds, cultures, and perspectives.
- experience the excitement of learning about people and places around the world.
- become more open to new ideas and ways of thinking, and unfamiliar situations.
- communicate with people who speak different languages.
- learn about sustainable practices in different parts of the world.
- discover their ability to act as global citizens and take action toward creating a more sustainable future.

ENGINEERING AND INVENTION AS A CAREER

They will

- realize that engineering and invention could be a career for them.
- use the skills they gain from the club to develop their critical thinking and resourcefulness.

Leading a Club

WHY A CLUB?

Kids love clubs! Kids like being part of a group that meets regularly and that works together toward a common goal. Also, they get to meet kids like them from a different country. That makes kids members of an *international club*!

CLUB MEMBERS AND NUMBER OF SESSIONS

- Recommended age group: 10–13 years old (but the material can be adjusted to accommodate other age groups)
- Recommended size: 9–12 kids
- Attendance: In each session, kids use what they learned in the previous session. Design Squad Global is not a drop-in club. It requires regular attendance by its members.
- Number of sessions: 6 sessions over 6 weeks
- Length of sessions: 60 minutes (minimum). **If you have more time, lengthen the sessions by 15, 30, or even 60 minutes.** There is enough to do in each session to keep kids engaged for extended periods of time. A longer session will allow you to run the club at a more leisurely pace.

WHAT YOU WILL NEED TO LEAD

Never led an engineering and invention activity? Never taught in a formal or informal educational setting? Not to worry! To lead a Design Squad Global club, all you need is dedication, a sense of adventure, and a passion for helping young people realize their potential.

CO-LEADER OR ASSISTANTS: HIGHLY RECOMMENDED!

You could certainly lead a club on your own, but we strongly encourage you to find a co-leader or an assistant (or 2). They can help your club run more smoothly by sharing the work and allowing more one-on-one time with kids. Plus, a co-leader or assistant gives you someone to discuss this great experience with!

A TIME COMMITMENT

Leading a club takes time. The club meets once a week for 6 weeks. You will need time to

- prepare for each of the sessions (about 60 minutes).
- lead the sessions (60 minutes per session, plus 30 minutes for setup each week). Extend sessions by 15, 30, or even 60 minutes if you have more time.
- collect and send "Partner Exchanges" (approximately 30–60 minutes) after Sessions 1, 3, and 5. In the Partner Exchanges, your club and your partner club communicate electronically, using forms, photos, sketches, and/or videos.

A COMMITMENT TO YOUR PARTNER CLUB

The connection between you and your partner club is a central part of kids' experience. **Kids are thrilled when they hear from their partner club—and they are terribly disappointed when their partner club does not communicate with them.** As partner club leaders, it is your responsibility that all kids—your club members and your partner's—have a positive experience. Do not let your partner club down: Always send your Partner Exchanges to your partner club!

WHAT IF YOU ARE LEARNING ENGLISH?

Design Squad Global is an international collaboration. English may be a second (or even a third or fourth) language for you and your club members. The activities allow everyone to practice English and have fun at the same time.

Here are some tips for helping club members who have varying abilities to speak English among their members:

- For each activity, there will be a handout describing new science and engineering concepts. If kids are not familiar with these concepts, explain them using kids' primary language.
- You could lead the activities in English but ask kids to hold discussions in their primary language. Or, you could lead the entire sessions in kids' primary language.

- During the Partner Exchanges, kids may want to say or write their comments, ideas, and questions in their primary language. Then you or your co-leader can translate what the kids said and wrote. You can email the document to your partner club.

ENGINEERING/INVENTION MATERIALS NEEDED FOR THE DESIGN SQUAD GLOBAL SESSIONS

You will need to collect or buy some of these materials before the club starts.

The engineering and invention challenges use inexpensive materials, such as scissors, cardboard, and duct tape.

- You will find a list of the materials you need (and the quantities) in the "Prepare Ahead of Time" section of each session.

- There is also a Master Materials List on page 23, if you prefer a single list of all the materials needed for all of the sessions.
- Create a "Recycled Materials Box" for your club. Fill a cardboard box with a variety of building materials. After completing each activity, kids will save the usable leftover materials in this box.
- Feel free to use substitutes if you cannot find some of the listed materials. Once you have tried the activity yourself, you will be able to judge what materials will work as substitutes.

SAFETY WHEN BUILDING

- Decide if you have the skill and experience to help kids use power tools safely.
- Make sure kids and leaders wear safety goggles and gloves, as needed.
- Wear thick gloves when cutting with knives.
- Only club leaders should cut items that are unsteady and hard to cut. The guide notes when this happens.

RECRUITING CLUB MEMBERS

- Display the Recruitment Poster or leave copies at your club site for kids and families.
- Send an email, letter, and/or the Recruitment Letter to parents of potential club members, giving the details of the club and encouraging them to tell their kids.
- Use the Recruitment Poster and the sample Recruitment Letter on the next 2 pages.
- Your club space may require permission forms for participation and photos. Request these forms from the director of the club space, print them out, and have them ready for kids' parents or guardians to fill out.

<SAMPLE RECRUITMENT LETTER>

Dear Family,

We would like to let you know about a very exciting opportunity:

_____

is offering children the chance to become members of a **Design Squad Global Inventing Green Club!**

Design Squad Global clubs introduce children to engineering and invention through fun hands-on activities.

Each week club members design, invent, and build projects that help solve environmental problems. Your child will have a great time AND the club will strengthen his/her problem-solving skills, creativity, confidence, and ability to work well with other children.

Your child will also talk with children from a different country! Each club is paired with a club from another part of the world.

The club may interest your child in a career in math, science, engineering, inventing, and the environment!

HERE ARE THE DETAILS:

Club Leader: _____

Club Leader Contact Information: _____

Age Group: _____

Number of Club Members: _____ (maximum)

Location: _____

Day and Time: _____

Number of Sessions: 6 one-hour sessions over 6 weeks

Attendance: Each week of the club uses skills and ideas from the previous weeks. Design Squad Global is not a drop-in club, and your child should expect to attend every week.

This will be a great opportunity for your child. If you are interested in having your child join the club or have questions, please contact me.

Sincerely,

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DESIGN squad® Global

INVENTING GREEN

AN ENGINEERING AND INVENTION CLUB

Want to have fun?

Design, invent, and build things!

You will learn to design inventions that protect the environment.

Be part of a weekly club!

Get to know kids from another country!

DATES: .....

TIME & LOCATION: .....

AGES: .....

CONTACT: .....

Put your teamwork and creativity to work! Make the world a better place!

JOIN THE CLUB!

PBS KIDS

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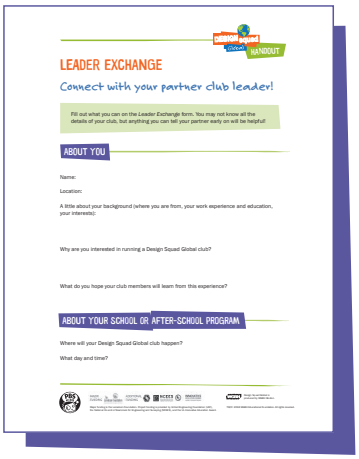
PARTNER CLUB LEADERS: WORKING TOGETHER

The relationship between you and your partner club leader is crucial in creating a successful virtual community.

Kids exchange engineering and invention experiences during the club and learn about each other's lives. They develop the following skills:

- Working in a team
- Communicating ideas effectively to people of different cultural backgrounds
- Learning about another country firsthand

The Leader Exchange Form: Becoming Partners


LEADER EXCHANGE

Connect with your partner club leader!

Fill out what you can on the *Leader Exchange* form. You may not know all the details of your club, but anything you can tell your partner early on will be helpful!

ABOUT YOU

Name:

Location:

A little about your background (where you are from, your work experience and education, your interests):

Why are you interested in running a Design Squad Global club?

What do you hope your club members will learn from this experience?

ABOUT YOUR SCHOOL OR AFTER-SCHOOL PROGRAM

Where will your Design Squad Global club happen?

What day and time?

It is important to start talking with your partner club leader **2 to 3 weeks before** your club begins. We have provided a form called the *Leader Exchange* to help you do this.

- Once you are matched with a partner club to work with, fill out the *Leader Exchange* and email it to each other as soon as you can.
- You will share background information about yourselves, the kids in your clubs, and the school or after-school program where your club happens. You will also share important information that will help you coordinate and run your clubs.
- You should talk at least once by phone or video chat before your clubs begin. The *Leader Exchange* form gives suggestions on how to organize a call using Skype, Google Hangouts, or another internet video or text chat service.

The Partner Exchanges: How Clubs Connect

The major way your clubs communicate is through the Partner Exchanges. These exchanges can include photos, sketches, and/or videos of kids and their projects. The sessions in this guide have *Partner Club Exchange* forms to make communication easier. Here is how the Partner Exchanges work:

- During the sessions, kids and club leaders document the projects with sketches, photographs, and videos and fill out the *Partner Club Exchange* forms.

- After the sessions, club leaders collect the sketches, *Partner Club Exchange* forms, and any photos/videos taken during the session and send them to their partner club.
- Use whatever method works best for you and your partner to send the sketches, photos, videos, and *Partner Club Exchange* forms.
  - Scan the sketches and forms and email them.
  - Photograph the sketches and forms and email those photos, along with any other photos you have.
  - Type the information from the forms into a new document and email it, along with any photos you have.
  - Send videos by placing them in a free download service such as Google Drive, Dropbox, or Box. Add permission for your partner to access the folder, and send a link to the folder to your partner.


PARTNER CLUB EXCHANGE

Help your partner club get to know you a little better! What are some things that you would like to tell them about you, your community, and your country?

INFORMATION ABOUT YOU!

Name:

Nickname:

One thing I like doing . . .

One thing interesting about me . . .

My favorite music/movies/hobbies/games . . .

One thing I like about my country . . .

QUESTIONS FOR YOUR PARTNER CLUB!

Now it's your chance to find out more about your partner club! Ask the kids something you'd like to know about their . . .

School:

Community:
(where they live)

Country:

Or ask another question:

- At the start of the next session, you will show kids what their partner club sent. You could print out the *Partner Club Exchange* forms, sketches, and photos or show them on the computer screen.

Partner Exchanges happen at these times:

SEND = when you send something from your club to your partner club

SHARE = when you share what your partner club has sent with your own club

SESSION	WHEN PARTNER EXCHANGES OCCUR
SESSION 1: GETTING STARTED	**SEND** *Partner Club Exchange* form to your partner club. Clubs share photos and facts about themselves, their communities, and their country. They also ask their partner club questions.
SESSION 2: THE FLIGHT TEST CHALLENGE	
SESSION 3: THE SNEAKER CHALLENGE	**SHARE** your partner's *Partner Club Exchange* form with your own club. **SEND** the answers to your partner club's questions.
SESSION 4: THE LIGHT PIPE CHALLENGE	**SHARE** your partner club's answers with your own club.
SESSION 5: THE WIND POWER STATION CHALLENGE	**SEND** *Share Solutions* handout to your partner club. Clubs share photos and descriptions of the designs they created during the club. If possible, they also share videos of kids presenting their designs.
SESSION 6: PARTNER EXCHANGE PARTY	**SHARE** the *Share Solutions* handout from your partner club with your own club.

DISCUSS TECHNOLOGY WITH YOUR PARTNER CLUB LEADER BEFORE THE CLUB STARTS

- Choose technology that works for both clubs for the Partner Exchanges. It might be email or optional video chats for communicating; a free download service such as Google Drive, Dropbox, or Box for sharing video and photo; a fax machine; or some other technology.
- Learn about the technology at both partner clubs. Many clubs will have slow or no internet access during club sessions. If a club has slow internet, they might not have a way to play videos. If this is true for your partner club, it would be frustrating for kids to receive a video and not have a way to watch it.

OPTIONAL WEB CHATS

Consider connecting your clubs through a live Web chat at some point over the 6 weeks.

A live chat can be challenging. Your club and your partner club may meet at different times. The clubs may be in different time zones! But try to arrange a video chat at a time when both clubs can gather (perhaps on a weekend). It will make the Partner Exchanges richer and more memorable.

Staying Connected

You and your partner club are truly partners: the clubs will do the same activities during the same 6-week period. You will deliver Partner Exchanges to each other during that time.

Work to stay connected! Stay on the same weekly schedule and send your Partner Exchanges on time. Your partner club will be eagerly waiting to hear from you. Your partner club will feel discouraged if they sent the Partner Exchange on time and your club did not.

WHAT HAPPENS IF CLUBS GET OFF SCHEDULE?

If you or your partner club's start date is delayed, if one club unexpectedly postpones a session, or if a club Is late in sending a Partner Exchange:

- Contact each other immediately and discuss how to get back on schedule.
- If your partner is behind in the schedule, your club could wait for them by doing the bonus activities in this Inventing Green guide or in the original DSG club guide.
- Another way for kids to spend a session while your partner club catches up is to show Design Squad Global videos. There are many interesting videos available on the website: **pbskids.org/designsquad**. Ask them to discuss what the saw.

Other Club Options

This guide is designed for Partner Exchanges between two partner clubs from different countries. However, if this international exchange is not possible, your club can partner with a club in a different state or province within your own country. Your club can even partner with other clubs at schools and after-school programs in nearby communities. Kids will learn many of the same skills as kids would by connecting with an international partner. Examples of such skills are teamwork, communication, recognizing different perspectives, and developing an interest in and respect for peers who come from different backgrounds.

Try to find a partner club that is different from your own, such as a club that is more urban or rural, or from a different educational system (such as a public, private, or charter school). An important goal of Design Squad Global is to help kids grow by exposing them to unfamiliar situations and environments.

You may be unable to connect with a partner club in your own or another country. Or, your partner club may drop out of the program. In these cases, continue without them. For kids, taking part in the club without a partner club can still be a rewarding experience. Kids learn about engineering, invention, environmental sustainability and the design process. Kids will gain experience collaborating with peers in their own club—sharing ideas and working together. They will also learn how to approach environmental sustainability problems from a global perspective.

DESIGN squad Global HANDOUT

LEADER EXCHANGE

Connect with your partner club leader!

Fill out what you can on the *Leader Exchange* form. You may not know all the details of your club, but anything you can tell your partner early on will be helpful!

ABOUT YOU

Name:

Location:

A little about your background (where you are from, your work experience and education, your interests):

Why are you interested in running a Design Squad Global club?

What do you hope your club members will learn from this experience?

ABOUT YOUR SCHOOL OR AFTER-SCHOOL PROGRAM

Where will your Design Squad Global club happen?

What day and time?

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Share a little about the school or after-school program where the club will meet. What activities do your club members do there?

ABOUT YOUR CLUB MEMBERS

About how many kids will be in your club?

What is the age range of kids in your club?

Do you have 60 minutes for each session—or is more time available?

What languages do your club members speak? Is English their second language?

HOW SHOULD WE COMMUNICATE?

You and your partner club leader will send each other Partner Exchanges consisting of text, photos, a scanned form, sketches, and possibly video. You will need to discuss what technology you each have available.

Is a camera or phone camera available for taking photos of kids and their projects?

Is a scanner available for scanning kids' forms and sketches?

Will you use email to send photos, forms, and sketches? Or a fax machine?

Are you able to take videos? How will you send them?

Will you be able to show videos in your club space?

Will you be able to chat through Skype, Google Hangouts, text messaging, or another method? (Scheduling a live chat will require knowing the time difference and finding a time when both clubs are available.)

FIND A TIME TO TALK BEFORE THE CLUB STARTS!

As partner club leaders, it is important that you introduce yourselves. Try to have at least one conversation before the club starts.

What is the best way for us to talk with each other?

☐ Phone
☐ WhatsApp
☐ Skype
☐ Google Hangouts
☐ another method? _____
☐ Facebook Messenger
☐ text messaging
☐ Twitter direct message
☐ Apple FaceTime

The time difference is _____ hours between our countries.
What days and times would be possible for a conversation? Would a weekday or the weekend be better?

_____in my country

_____in my partner club's country

THINGS TO TALK ABOUT WITH YOUR PARTNER

Your Countries and Communities

Give details to your partner that will excite kids about your country: famous people, attractions, distinctive geography, languages, customs, holidays, food, or ethnic and cultural groups.

Schedule Dates for Running the Club

A worksheet is provided on the next page so that you and your partner leader can start to coordinate your schedules. Keep the following in mind:

Your clubs will need to do the same sessions during the same week.

- The Partner Exchanges will also need to happen during the same week.
- Check your calendars. Are there holidays, school breaks, or other events that might require adjusting the club schedule?
- If one club skips a week, the other club may choose to skip that week, too. Or, clubs can do the bonus activities (see page 103 and page 115) while they wait for their partner club.
- Before the first session, make sure your partner club can start on the agreed-upon date.
- Email, text, or message frequently about the schedule. If you need to reschedule a session, tell your partner club right away.

PARTNER CLUB SCHEDULING WORKSHEET

Use this worksheet of each session and partner exchange to plan and match your club days.

PART 1	DATE OF SESSION		PARTNER EXCHANGES
	Your Club	Your Partner Club	
SESSION 1: GETTING STARTED			**SEND** *Partner Club Exchange* form to your partner club
SESSION 2: THE FLIGHT TEST CHALLENGE			
SESSION 3: THE SNEAKER CHALLENGE			**SHARE** your partner's *Partner Club Exchange* form with your own club **SEND** your answers to your partner club's questions
SESSION 4: THE LIGHT PIPE CHALLENGE			**SHARE** your partner's answers with your own club
SESSION 5: THE WIND POWER STATION CHALLENGE			**SEND** *Share Solutions* handout
SESSION 6: PARTNER EXCHANGE PARTY			**SHARE** your partner's *Share Solutions* handout

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CHECKLIST:
RUNNING YOUR DSG CLUB

Prepare for Club Meetings

- ☐ Find a co-leader or assistant (strongly recommended)
- ☐ Locate a meeting place for your club with plenty of room, tables for materials and building, a recycling bin, and a trash container. Get permission to use the space.
- ☐ Find a storage space where you can leave materials and kids' designs between club meetings. Get permission to use the space, if necessary.
- ☐ Determine whether or not there is a computer and an internet connection available.

Work Together with Your Partner Club Leader from the Beginning

- ☐ Learn how the Partner Exchanges work.
- ☐ Email, call, text, or message your partner club leader as soon as possible.
- ☐ Fill out the *Leader Exchange* form and email it.
- ☐ Connect with a video chat, phone call, or instant message chat.
- ☐ Check your calendars. Are there holidays, school breaks, or other events that might require adjusting the club schedule?
- ☐ Send an email, text, or instant message to your partner club leader between the club sessions to say hello and stay connected.

Recruit Club Members

- ☐ Display or distribute the *Recruitment Poster*.
- ☐ Send parents of potential club members your recruitment letter.
- ☐ Get permission forms for kids' participation and photos, if needed.

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Read Through the DSG Inventing Green Guide

- ☐ Get an overall sense of all the sessions.
- ☐ Look closely at the Prepare Ahead of Time sections in each session. They say what you need to do to get ready.
- ☐ Do each activity yourself before your club meets. Schedule time for this important step.
- ☐ Read Going Deeper: Tips for Leading Design Squad Global Sessions on page 27.

Print and Photocopy Membership Cards, Handouts, and Posters

Print and photocopy the membership cards, handouts, and posters for each session.

The poster you will use the most is *The Design Process*.

- ☐ *The Design Process* poster is located on page 60.
- ☐ Before the first session, you can print copies for each kid or print one for the whole group. The poster can be printed in very large sizes and still look good if you want a big poster. Reuse the wall poster at each session.

Buy/Collect Materials for the Activities

Collect/buy materials for the activities.

- ☐ You may want to gather all the materials at the same time using the Master Materials List.
- ☐ You can also gather materials before each session. Each session lists the materials and quantities for the activity.
- ☐ Feel free to substitute other materials. How will you know if a substitution works well? Try it out yourself.
- ☐ Create a Recycled Materials Box and fill it with a variety of scraps and supplies. Suggestions for the box are listed in Session 1.

DESIGN squad Global HANDOUT

MASTER MATERIALS LIST

These are the materials you will need for the hands-on activities. To see more details for each activity, look at the materials lists in each session, under Prepare Ahead of Time. The materials are inexpensive and most are easy to find. The list also suggests substitutions for the materials, and you should feel free to try your own alternative materials as well.

CLUB = 9–12 KIDS

	Item	Session/Activity
	**handouts, posters, and Partner Exchange forms** The handouts, posters, and forms to print and photocopy are located in the guide.	**All sessions**
	**pencil and scrap paper** (for drawing) (1 for each club member)	**All sessions**
	**small stickers** (for membership cards) substitute: mark the cards with pen (1 for each club member for each session)	**All sessions**
	**masking tape (painter's tape)** (1 roll for 2–3 teams to share)	**All sessions**
	**large cardboard box** (for Recycled Materials Box) Fill with various building materials that you find for free. Store useable leftover materials. (1 for the whole club)	**All sessions**

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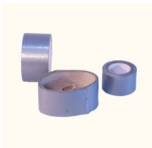
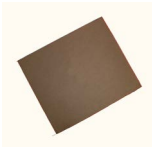
	**camera/phone** (for the Partner Exchanges and for the optional testing stage in Session 5) (1 for the whole club)	**Sessions 2–5**
	**scissors** (1 pair for 2–3 teams to share)	**Sessions 3–5**
	**duct tape** substitute: masking tape, if necessary (1 roll for 2–3 team to share)	**Sessions 3–5**
	**pieces of cardboard** Any size and thickness	**Sessions 3–5**
	**large piece of paper or cardboard** (for the Design Board) about 2–3 feet (50–100 centimeters) square (1 for the whole club)	**Session 1: Getting Started**
	**thread** ordinary sewing thread (1 spool for the whole club)	**Session 2: Flight Test** **Session 5: Wind Power**
	**metal spoons** smaller, teaspoon size, work best (1 for each club member)	**Session 2: Flight Test**
	**paper clips** larger-size clips work best	**Session 2: Flight Test** **Session 5: Wind Power**
	**letter-sized or similarly sized scrap paper** used for making airplanes (3–5 sheets for each club member)	**Session 2: Flight Test**
	**stopwatch, clock, or timing app on a phone** (1 for the whole club)	**Session 2: Flight Test**

Note: There are many different possibilities for sole designs in Session 3: Sneakers. Kids may not end up using all of the items listed in the session—but the more choices you supply them with, the more design ideas you may spark.

scrap materials for cushioning
various natural, recycled, and reusable materials (some of each material for each team, if possible)

Session 3: Sneakers

plastic water or soda bottle
(1 for the whole club)

Session 3: Sneakers

reflective material
examples are aluminum foil or the silver inner lining of a clean, empty snack bag (1–2 sheets for each team)

Session 4: Light Pipes

thick paper
examples are poster board, card stock, and file folders (1–2 sheets for each team)

Session 4: Light Pipes

small cardboard boxes
(1–2 for each team)

Session 4: Light Pipes

transparent tape
(1 roll for 2–3 teams)

Session 4: Light Pipes

mirror
(optional) for demonstration of reflection
(1 for the whole club)

Session 4: Light Pipes

wooden skewers
vegetable or meat skewers, at least 6 inches (15 centimeters) long
Substitute: any straight, thin wooden stick, if necessary (1–2 for each team)

Session 5: Wind Power Station

	**drink bottles with caps** 1-liter bottles work best, but 2-liter bottles also work. Bring extra for teams that want to redesign (2–3 for each team)	**Session 5:** **Wind Power Station**
	**cardboard boxes** Boxes with one short length and one taller length. Examples are shoeboxes, shipping boxes, and shirt boxes. **(1–2 for each team)**	**Session 5:** **Wind Power Station**
	**plastic straws** (1–2 for each team)	**Session 5:** **Wind Power Station**
	**permanent marker or crayon** (1 for the whole club)	**Session 5:** **Wind Power Station**
	**portable electric fan or large piece of cardboard** used to create wind to test prototypes (1 for the whole group)	**Session 5:** **Wind Power Station**
	**small plastic bags** used to hold weight (3 for the whole club)	**Session 5:** **Wind Power Station**
	**some sand or gravel** substitute: small heavy objects such as metal washers, rocks. (enough material to create several varying weights in the plastic bags above)	**Session 5:** **Wind Power Station**
	**thumbtack or pushpin** used to make holes in plastic or cardboard (1–2 per club)	**Session 5:** **Wind Power Station**
	**Hammer and small nail** (optional) for making holes in plastic (1 for the whole club)	**Session 5:** **Wind Power Station**

GOING DEEPER

Tips for Leading Design Squad Global Sessions

MANAGING THE CLUB

1. Do the activity yourself (and with a co-leader/assistant, preferably).
The hands-on experience you get from doing the activities is crucial to helping kids during the sessions. Doing the activity provides

- firsthand knowledge of each step.
- understanding of what kids will need help with.
- a sense of the activity's length and how much time is needed for each step.
- ideas for substituting materials needed for the activity. You may not always be able to get the exact materials suggested.

2. Divide up tasks with your co-leader/assistant.
Your club will run more smoothly if you divide up the responsibilities with your co-leader/assistant ahead of time. Both you and your club members will have more fun.

- You might lead kids through the activity while your co-leader takes photos.
- You might help a slower group finish their activity while your co-leader discusses the activity with the kids who are already finished.
- You might help kids rehearse their design presentations while your co-leader videotapes the kids who are ready to do their presentations.

3. Extend the length of your sessions, if possible.
Many clubs will only have 60 minutes for each session, but if you can add extra time, it is helpful to make your sessions longer.

- The engineering and invention activities are open-ended. By extending the sessions by 15 or 30 minutes (or more), kids can explore further.
- Engineering and invention redesign their projects over and over again in order to improve the outcome. Kids in the club will have time to test, evaluate, and redesign their projects until they are happy with their designs. This process will help kids begin to think like engineers/inventors and help them develop perseverance.

4. Focus on time management.

Kids have a limited amount of time to complete their hands-on projects. As club leader, your job is to keep kids on time and help them finish within the time you have. This will help kids develop time management skills. These skills are a vital part of how engineers and inventors operate in the real world: with time limitations and budget constraints.

- Every 10 minutes or so, announce how much time kids have left.
- If you notice kids focusing too much on an early step of the design process, urge them to move to the next step.
- Encourage kids to do the best they can with the time. That is how engineers and inventors work!

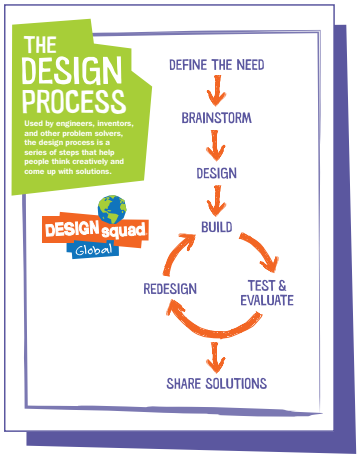
ENSURING EDUCATIONAL VALUE AND SUCCESS

1. Encourage creativity and problem-solving.

Instead of asking kids to follow step-by-step directions, you will ask them to use their creativity and problem-solving skills to build their designs.

- Many kids are unfamiliar or understandably uncomfortable with an open-ended, problem-solving approach.
- As club leader, your role will be to encourage kids to trust their creativity and problem-solving skills. This resourcefulness helps build confidence and pushes kids to become independent thinkers.
- There may be times when the best way to help is to stand back and let kids solve their problems on their own!

2. Emphasize the design process.



- The best way to encourage open-ended problem-solving is asking kids use the design process. The design process is a series of steps that help engineers, inventors, and others think creatively and find solutions. The design process gives kids a framework for thinking through and solving problems.
- Display *The Design Process* poster during every session. Each activity is structured around its steps. For more information, see A Closer Look at the Design Process on page 33.

3. Ask open-ended questions.

An open-ended question usually cannot be answered with just 1 or 2 words, or with a simple *yes* or *no*. Open-ended questions encourage kids to explain and expand upon their thoughts. Asking open-ended questions helps kids think for themselves and explore their ideas further.

Open-ended questions frequently begin with *how*, *what*, or *why*:

- How do you want your design to work differently? What else could you try?
- What is the best feature of your design? Why?
- Why was it important to test your design? What did testing show you?

4. Let kids try things that do not work.

Help kids understand that trying something that does not work is a great way to learn. In fact, failure is part of the design process! Explain that it is natural to feel disappointed when something you make fails. Each time engineers and inventors test something that fails, they can learn to improve it.

The Design Squad Global motto is: "Fail fast, succeed sooner." This means kids should test an idea quickly and not waste time decorating their first version!

5. Balance teamwork and competition.

Competition may add fun and excitement to the activities for some kids. But too much of a focus on competition takes away from kids' opportunities to learn. When kids are focused on "winning" they do less exploring and problem-solving. Learning through collaboration and teamwork is important for developing both engineering skills and global competence.

The sessions gradually include more and more teamwork. A goal of Design Squad Global club is to help kids improve their ability to work with others over time.

6. Help kids develop global competence.

At the heart of the club is the opportunity for kids from different parts of the world to explore the interconnected world we live in. Kids will experience the excitement of learning about (and from) people and places around the world. Their growth in global competence will encourage them to develop an openness to unfamiliar situations, new ideas, and new ways of thinking.

Over the 6 sessions, kids listen to, share with, and learn from kids from another part of the world.

7. Let kids connect.

A simple but important part of helping kids develop global competence is connecting them with their partner club members through the Partner Exchanges. Stay on schedule and in regular communication with your partner club leader throughout the club. If club leaders make it possible for kids to connect, kids will do the rest with the leader's support.

8. Encourage kids to start thinking about career choices.
Through the Design Squad Global club, you may inspire some kids to consider engineering and invention as a possible career path.

- Today's engineers and inventors are needed more than ever to solve the planet's problems.
- Many engineers seek a Professional Engineer license in order to lead engineering projects that many people depend on—and to earn higher pay.
- To be more effective, engineers and inventors must develop global competence. They need to understand the world in order to design solutions for it.

No matter what kids' career aspirations are, the club will provide the opportunity to build problem-solving skills that will serve them well. Kids will

- learn to evaluate and analyze problems and persevere.
- grow confidence in their creativity, critical thinking skills, and resourcefulness.
- discover their ability to act as global citizens and make a difference in the world.

Talking with Kids about Engineering and Invention

WHO, ME? AN ENGINEER? AN INVENTOR?

Few kids can say what engineering is or what an engineer does. (Few adults can, either.) And while more kids may know what an inventor does, it is still hard for some to picture themselves inventing something.

Doing hands-on activities helps kids see the possibilities for invention and engineering in their own lives. They experience fun and excitement firsthand through the club activities. Time spent designing and building is also a great opportunity to talk to them about careers. Here are some tips on what you might say.

WHAT IS AN ENGINEER? WHAT IS AN INVENTOR?

An engineer or inventor may be designing a high-speed train or a wheelchair. But they use creativity, problem-solving skills, and knowledge of technology, mathematics, and science to build things that matter. They make change people's lives and help build a better world. What is the difference between an engineer and an inventor?

- **Engineers** design things that improve the world around us. A materials engineer might create compostable food packaging from corn or sugarcane. An aerospace engineer might build a satellite that orbits the earth to take ocean measurements and protect

ocean wildlife. Many engineers seek a Professional Engineer license to show employers that they have the experience and skill to do big assignments.

- **Inventors** use their creativity to design useful things that did not exist before. Inventors sometimes use engineering methods to create new solutions, but many do not. An invention can be a thing (a winter coat made from recycled plastics) or an idea (a new recycling plan for a school).

WHAT'S GREAT ABOUT BEING AN ENGINEER OR INVENTOR?

- **Being creative.** Imagine inventing solutions no one else has thought of. Or think about improving something that already exists by making it faster, stronger, less expensive, easier, safer, more fun, more useful, more efficient, or more beautiful!
- **Connecting with other people.** Engineering and invention take teamwork. Engineers and inventors work with smart, inspiring people.
- **Changing the world.** Engineering and invention are powerful tools for change. Engineers and inventors can save lives, protect the planet, reduce poverty, and expand our abilities to communicate with each other. They can help solve big problems like access to clean water and affordable energy.
- **Developing global competence.** To truly be effective, engineers and inventors must develop "global competence." If you want to design solutions that make the world a better place, you first need to understand the world!

Talking with Kids about Environmental Sustainability

FIRST, WHAT IS IT?

Environmental sustainability may sound like big words to kids, but it is simple: Create things today that do not hurt the planet tomorrow. A sustainable invention can be produced again and again with minimal environmental harm.

During the following sessions, kids will talk about the *life cycle* of designs:

- Where will the raw materials come from to make the invention?
- How will it be manufactured? How much energy will be used to make it?
- What will happen to the invention when it is no longer useful? Can it be recycled, reused, or composted?

"Inventing Green" sometimes means creating inventions specifically to solve environmental issues (such as inventing a new solar panel). But inventing green also means solving everyday problems in an environmentally friendly way (such as designing a recycled coffee cup that folds down to make its own lid).

The challenge to the next generation of engineers and inventors will be to improve standards of living for everyone and to do this in a way that does not make our communities and planet unlivable. The environmental issues discussed in this guide are based on the United Nations' Sustainable Development Goals. These 17 goals describe ways humans can continue to develop and thrive with fewer environmental consequences. The goals include ending hunger, promoting clean water and sanitation, developing clean and affordable energy, and designing factories so that more consumer products are environmentally safe to make and to use.

FIND OUT WHAT KIDS KNOW

Ask questions to learn what kids know already about a problem. The activities in this guide start by defining environmental sustainability needs. Club members might know of examples of serious problems such as flooding or living without electricity. Human creativity thrives when people are challenged to find solutions to real problems.

Asking kids what they know connects with them in a different way. Bringing out their knowledge helps them participate actively by adding their experiences and understanding to the club's discussion. This personal involvement will make them more likely to persevere in understanding the problem or inventing the solution. Kids' contributions may also help you identify misinformation or gaps in their knowledge to explore later.

PROMOTE CRITICAL THINKING AND SUSTAINABILITY

One thing engineers are really good at is studying the benefits and the problems of complex systems. Engineers are specially trained to consider many factors in order to find the least harmful solution. During the sessions, kids think critically about how their designs and materials impact the environment. Using the design process, they brainstorm and evaluate various materials. For example,

- One material may be easy to recycle, but it produces waste during manufacturing.
- Another material is difficult to recycle, but it is made from old, discarded products. This material reduces waste overall.

Having kids think critically about real-life environmental problems helps them develop valuable problem-solving skills. Skill in considering the benefits/problems of an idea will benefit them in their everyday lives, school, and later in the workplace.

YOU MAY BE TALKING TO A FUTURE ENVIRONMENTAL ENGINEER!

Kids using the Inventing Green guide learn about environmental needs of communities across the planet. The global perspective gives them an understanding of how such problems are connected between people living in distant places. A focus on engineering solutions gives kids a path to help fix those problems in the future.

There are no simple answers to environmental problems. But solutions are not out of reach either. This guide provides a fun and engaging exploration of global environmental topics that may inspire them to continue to study engineering or practice invention professionally one day. Kids in your club may one day design a helpful solution to a serious environmental problem.

SHARE THE DESIGN SQUAD GLOBAL WEBSITE

Another great way to inspire kids to consider engineering or invention as a career is to share the large number of videos and activities on the Design Squad Global website: **pbskids.org/designsquad**.

A Closer Look at the Design Process

The design process is a series of steps that help people think creatively and find solutions. It is used by engineers, inventors, and many other problem solvers.

DEFINE THE NEED

To "define the need" means to ask the following:

- What is a problem that a person or a community has?
- Who has the problem?
- How can we help them?

Defining the need can be the most overlooked step in the design process. People often want to rush to solve an issue before truly understanding it. (Some of your club members will probably do this.)

It is hard for an engineer or inventor to find an effective solution without first thinking about the issue and people he or she is designing for. That is why developing global competence—the ability to communicate and collaborate with people with different backgrounds, cultures, and perspectives—is such an important part of engineering and invention.

BRAINSTORM

Once an engineer or inventor understands the need, it is time to brainstorm ideas for possible solutions. Brainstorming relies on the creativity and problem-solving skills of a team working together.

- More people with different perspectives are always better.
- More ideas are also better. The quality of the ideas does not matter at this early stage. Sometimes a wild or impractical idea can lead to a big breakthrough.
- The last step of brainstorming is to narrow down the ideas by giving them the **NUF** test: Is the possible solution **N**ew, **U**seful, and **F**easible?

DESIGN

Once you have an idea, sketch out possible solutions. The Design step helps plan for materials and it helps you talk about your idea to other members of your team.

BUILD, TEST, EVALUATE, AND REDESIGN

On *The Design Process* poster, the words *build, test, evaluate, and redesign* form a circle. These four steps will repeat in a circle until a design is successful. This cyclical approach to improving an idea is a very powerful part of the design process. Designs do not always succeed at first. Failure is an opportunity for improvement. Engineers and inventors who redesign after each failure improve their designs each time.

SHARE SOLUTIONS

This last step in the design process is very important. When kids share their solutions with others, they learn what others think of their designs. Sometimes kids (and many adults) have in mind certain ideas of how their designs will be used and understood. The observations of peers can change the designer's thinking and help improve their solutions.

ASSESSING YOUR CLUB MEMBERS' GROWTH (OPTIONAL)

Many leaders are amazed at kids' growth in skill and understanding over the course of the club sessions! As club leader, you may want a way to measure your members' progress.

Ask kids questions during the first and last sessions of the club. Record their answers on the form in Session 1 on page 48. Then compare answers. You will likely see great improvement in kids' understanding of engineering and invention and in their global competence.

By recording kids' answers and reflecting on their progress, you will be able to evaluate the educational value and effectiveness of the club. You may want to share the assessment with parents, potential club leaders, after-school program leaders, or classroom teachers who have provided the club space. You may want to use the assessment to attract funding for future Design Squad Global clubs. Also—give yourself credit for inspiring the next generation of engineers, inventors, and global citizens!

SESSION 1: GETTING STARTED

(60 MINUTES)

OVERVIEW

WELCOME TO THE DESIGN SQUAD GLOBAL CLUB! (20 minutes)

Watch the Design Squad Global video to learn more about the club.

Meet your club members and talk about solving real-world problems through engineering and invention.

A VERY BIG BRAINSTORM! (20 minutes)

Sketch inventions that improve your local communities and the world.

FIND OUT ABOUT YOUR PARTNER CLUB! (20 minutes)

Who are they and where are they from?

AFTER THE SESSION: SEND YOUR PARTNER EXCHANGE

Leaders send the *Partner Club Exchange* forms to their partner club.

SESSION GOALS

ENGINEERING AND INVENTION

Kids learn **key science concepts:**

- **Renewable:** In energy, a source that cannot be used up.
- **Sustainable:** A way of designing things today that will not hurt the environment tomorrow.

ENVIRONMENTAL SUSTAINABILITY

Kids consider solutions to real-world problems such as lack of food, unclean water, lack of renewable energy, affordable energy, and an unhealthy environment.

GLOBAL COMPETENCE

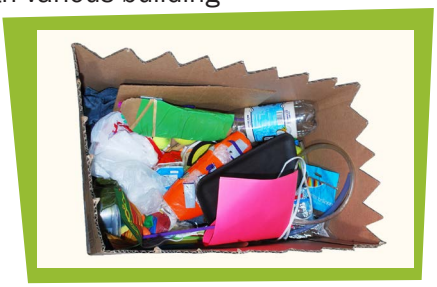
Kids begin to develop "global competence," the ability to communicate and collaborate with people from different backgrounds, cultures, and perspectives.

BEFORE & AFTER (OPTIONAL)

Use the *Assessment* form to record kids' answers to questions in this session about engineering and invention. You will ask similar questions in the last session and will then be able to see how much your club members have grown.

PREPARE AHEAD OF TIME (about 60 minutes)

1. **Relax and get ready to enjoy the session!** Kids love the invention process and making things. No matter how successful the final products, they will have fun.
2. **Read through these instructions** and make notes.
3. **Divide up the tasks** with your co-leader/assistant.
4. **Check that you have received permission forms,** if you need them from the parents/guardians of kids joining the club.
5. (optional) **Decide if you would like to take notes for the *Assessment* form.** Many leaders are amazed at how much kids learn and grow over the course of the club sessions! During the session, you will ask some basic questions about engineering, invention, the environment, and global competency. These questions are also listed in the *Assessment* form on page 48. If you decide to compare your club members' knowledge between the first and last sessions, write kids' answers on the form and save it for Session 6.
6. **Create a Recycled Materials Box.** Fill a cardboard box with various building materials, such as small cardboard boxes, clothespins, wooden skewers, chopsticks, leather scraps, zip-ties, wire, sheets of cardboard, plastic bottles, toothpicks, aluminum foil, popsicle sticks, bottle caps, string, bubble wrap, pieces of wood, sticks, binder clips, and small plastic bottles. If you have a drawer full of junk at home, this may be a good time to clear it out! After completing each activity in the upcoming sessions, you can also save the usable leftover materials in this box.



7. **Gather materials.**

For each club member:

- ☐ scrap paper for drawing
- ☐ pencil

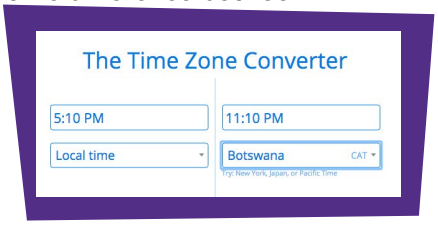
For the whole club:

- ☐ 2–3 pens for kids to fill out their DSG Membership Cards
- ☐ Enough small stickers to place on each club members' DSG Membership Card after they complete each of the six sessions. (Kids love stickers, but if you cannot find them, you can mark the membership cards with a pen.)
- ☐ roll of masking tape (painters tape) or clear tape for the Design Board
- ☐ a large piece of paper or cardboard, about 2–3 feet across (50–100 centimeters) and 2–3 feet high (50-100 centimeters).
- ☐ (optional) colored markers/pencils for coloring partner countries on the World Map

8. **Make a Design Board**. Divide it into 4 squares with a pen or pencil and label them: Food, Water, Energy, and Environment.
9. **Print a map showing both partner locations:**

- Go to Google Maps (**maps.google.com**) and zoom out until you can see the locations of your club and your partner's club on the map.
  - Hover over your club's location and right-click (Apple computers use control-click). A dialog box will appear. Choose the "Measure distance" option. A little circle will appear above the location.
  - Hover over your partner's location and use a normal click. A line connecting the 2 clubs' locations will appear with the distance between them in miles and kilometers.
  - Take a screenshot and print the map (or show it live to your club if you will have a computer and an internet connection at the club's space).
  - If you cannot access the map, use the World Map handout instead, provided on page 45.

10. **Try to have a computer** available in your club setting.
11. **Find a time zone converter on the internet:** Calculate the time difference between your club and your partner club. Take a screenshot of the time zones and print it (or show the time zones live during the session). Websites you can use:
    - **www.thetimezoneconverter.com** (Once loaded, this page works even without an internet connection.)
    - **www.timeanddate.com/time/map**



12. **Download the Welcome to DSG! video from the website.** (The download button is on the page just under the video.)

    www.pbslearningmedia.org/resource/dsg16-sci-welcometodsg/welcome-to-dsg/

    You will be showing the video during the session. Test it out ahead of time to make sure you can both see and hear it before kids arrive. (Project the video if you can.)

13. **Print the handouts.**

For each club member:

- ☐ **Poster:** *World Map* on page 45
- ☐ **Handout:** *DSG Membership Cards* (Print in color if you can.) on page 46
- ☐ **Handout:** *Partner Club Exchange* on page 47
- ☐ **Form:** *Assessment* on page 48


PARTNER CLUB EXCHANGE

HANDOUT

Help your partner club get to know you a little better! What are some things that you would like to tell them about you, your community, and your country?

INFORMATION ABOUT YOU!

Name:

Nickname:

One thing I like doing . . .

One thing interesting about me . . .

My favorite music/movies/hobbies/games . . .

One thing I like about my country . . .

QUESTIONS FOR YOUR PARTNER CLUB!

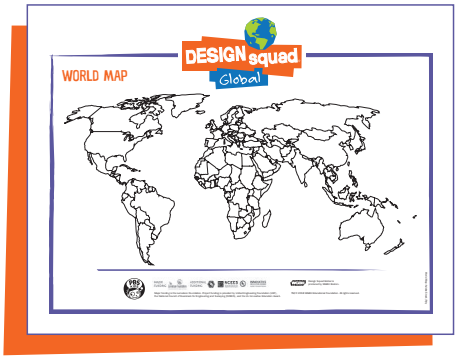
Now it's your chance to find out more about your partner club! Ask the kids something you'd like to know about their . . .

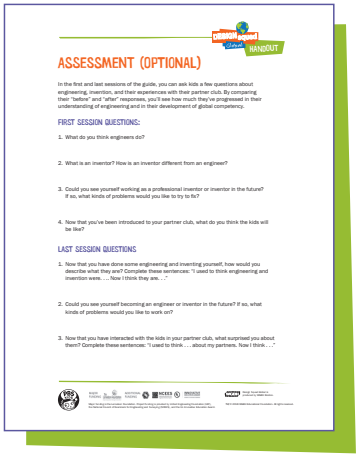
School:

Community:
(where they live)

Country:

Or ask another question:




ASSESSMENT (OPTIONAL)

HANDOUT

In the first and last sessions of the guide, you can ask kids a few questions about engineering, invention, and their experiences with their partner club. By comparing their "before" and "after" responses, you'll see how much they've progressed in their understanding of engineering and in their development of global competency.

FIRST SESSION QUESTIONS:

1. What do you think engineers do?

2. What is an inventor? How is an inventor different from an engineer?

3. Could you see yourself working as a professional inventor or inventor in the future? If so, what kinds of problems would you like to try to fix?

4. Now that you've been introduced to your partner club, what do you think the kids will be like?

LAST SESSION QUESTIONS

1. Now that you have done some engineering and inventing yourself, how would you describe what they are? Complete these sentences: "I used to think engineering and invention were. . . . Now I think they are. . ."

2. Could you see yourself becoming an engineer or inventor in the future? If so, what kinds of problems would you like to work on?

3. Now that you have interacted with the kids in your partner club, what surprised you about them? Complete these sentences: "I used to think . . . about my partners. Now I think . . ."

LEAD THE SESSION (60 minutes)

WELCOME TO THE DESIGN SQUAD GLOBAL CLUB! (20 minutes)

Welcome your club members! Ask them to introduce themselves. Then, describe the club: *Design Squad Global is about engineering and invention! You will work together to design and build fun projects.*

Watch

Tell kids the Welcome to Design Squad Global! video explains more about the club and **start the video.**

Introduce engineering by asking kids:

- *What do you think engineers do?*

Ask the group to talk about examples that they have seen. Allow a few minutes for kids to discuss their observations with each other and their answers.

If kids are unsure of the answer, share these definitions and examples:

- **Engineers design things that improve the world around us.**
- **Some examples:**
  - A power plant engineer might create electricity using the wind or the sun.
  - An aerospace engineer might build a satellite that orbits the earth, taking measurements of coral reefs and fish populations to protect ocean wildlife.
  - A materials engineer might design things that will not pollute the environment, such as food packaging made from corn or sugarcane.
- Engineers earn a license to show that they have the experience and knowledge to make things that keep people safe. For example, some engineers design and check roller coasters at theme parks (see the story of Anthony Oyatayo below).

Ask kids to talk about examples of engineering that they have seen. Allow a few minutes for kids to discuss their examples with each other.

Photo:
Anthony Oyatayo

Meet a Roller Coaster Engineer!

Anthony Oyatayo is a licensed mechanical engineer. For Universal Studios in Los Angeles, California, Anthony loves his work maintaining roller coasters (such as the Transformers ride in the drawing) and making sure the rides are safe. He says: "It's great to know the work engineers do allows guests to be happy at the park."

Next, introduce invention by asking kids:

- *What is an inventor? How is an inventor different from an engineer?*

Ask the group to talk about inventors that they have seen or read about. Allow a few minutes for kids to talk with each other.

If kids are unsure of the answer, share these definitions and examples:

- **Invention is a creative process of designing something useful that did not exist before.**
- **Some examples:**
  - a warm winter coat made from recycled plastic
  - an electric generator that uses the ocean tides to make power
  - a shoe with a sole that naturally falls apart in the ground after it is thrown away
- **How do you become an inventor? You already are!** *We all solve problems through inventive thinking, whether it is finding a way to keep a window open, stay dry in the rain, or build a playhouse with scrap materials.*
- **Inventions can be products**—*like a floating machine that sucks up plastic from the ocean—or they can be a new process for solving a problem—like a new way to arrange music or a new recycling plan for a school.*

Talk to kids about engineering and invention:

- **Engineers and inventors have a lot in common.** *Most inventors use engineering every day, and most engineers have invented new things.*
- **You do not have to worry about knowing the "right" answer as an inventor or engineer**—*there are many different ways to solve the same problem.*
- **Failure is part of the invention and engineering process.** *You learn a lot from your mistakes and can use what you learn to make your invention better.*

Some Failures Become Great Inventions

- Chocolate chip cookies were invented when a baker did not have the right ingredients to make her favorite all-chocolate cookies. Instead, she added chocolate chunks to the dough and thought the oven would eventually melt them into the dough. But when the cookies were done, they still had whole pieces of warm chocolate in them—and tasted great!
- Bubble wrap was invented by engineers trying to create stylish wallpaper. It turned out to be better for cushioning packages in the mail!
- The microwave oven was invented by an engineer working to improve radio signals, but his coffee kept heating up in front of the antenna. His radio inspired a new kitchen appliance!

Ask:

- *Could you see yourself working as a professional inventor or engineer in the future? If so, what kinds of problems would you like to try to fix?*

Design Squad Global Membership

Give kids the membership cards. Provide pens for kids to write their names on their cards. Explain that for every engineering challenge or activity they complete, you will give them a sticker on the back of their cards.

Getting to know kids from another part of the world!

Ask: *Why do you think this club is called Design Squad* **Global***?* Wait a moment for kids to think. If they are unsure, explain that it is an international club with members around the world. **Tell them about their partner club:**

- *You have a partner club somewhere else in the world that will be doing the same engineering and invention activities you will be doing!*
- *You will not actually meet these kids in person—they live thousands of miles away in a different country.*
- *But you will share ideas, photos, and videos with each other. You will show them the projects you build.*
- *You can tell each other about your countries, your schools, and fun things, such as the music, TV shows, and movies you like.*
- *And, there will be a party at the end for you to look at all the photos and videos—and to eat delicious treats!*

Ask kids:

- *What do you think the kids will be like? Why do you think that?*

START THE VERY BIG BRAINSTORM! (20 minutes)

Tell kids they are going to brainstorm solutions to some of the planet's very big problems. Ask and discuss:

- *What are some of our planet's biggest problems?* (If kids unsure of the answer, give examples such as a lack of food, unclean water, lack of renewable energy and affordable energy, and an unhealthy environment in the ocean and on land.)
- *Where have you seen these problems in your own neighborhood or town/city?* (For example, products in stores and markets, such as cookies and crackers, sometimes use wasteful plastic packages.)
- *Are there places in your community that do not have enough electricity?* (Some people do not have electricity to power lights at night. Sometimes the electricity stops working altogether.)
- *How could electricity be more available?* (Wind turbines, solar panels, and hydroelectric generators could provide electricity in a way that is better for the environment than oil or gas. These are called renewable energy sources because they cannot be used up.)

- *What could be invented to help grow more food or preserve food longer?* (New watering systems for crops and refrigerators could prevent food from spoiling.)

Brainstorm

Tell kids they will do some creative thinking on problems that need attention in their communities. Ask and explain:

- *As an inventor, what could you create to help with one of the problems we just talked about? What do you want to fix in your own neighborhood?*
- **Remind kids:** *Invention is a way to make something faster, stronger, easier, safer, and better for the planet!*
- *For the next 5 minutes, we will brainstorm inventions.*
- *What is a brainstorm?*

If kids are unsure, explain:

  - *A brainstorm is a way to get lots of new ideas on a topic.*
  - *Try to build off each other's ideas.*
  - *Everyone takes part. We all have different experiences and interests that can help make ideas better.*
  - *There are no bad ideas in brainstorming. It is ok to think of inventions that are surprising or a little weird. Someone's idea might become a new solution to a serious problem. Examples are a giant, floating machine that sucks plastic out of the ocean or a way to use a sheep's wool to make environmentally friendly sneakers.*

Allow 5 minutes for the kids to discuss their ideas.

Design

Tell kids they will work by themselves to draw an invention they would like to build someday. On their drawings, they should add labels to show the parts and the materials the invention would use.

Ask them how their invention would solve a very big problem:

- *How would the invention work?*
- *What problem does it solve?*
- *Why did you choose that invention?*
- *What is your invention made of?*

Give everyone pencils and paper and ask kids to sketch their ideas. **Allow 10 minutes for them to sketch their designs.** When done, ask kids to explain their inventions.

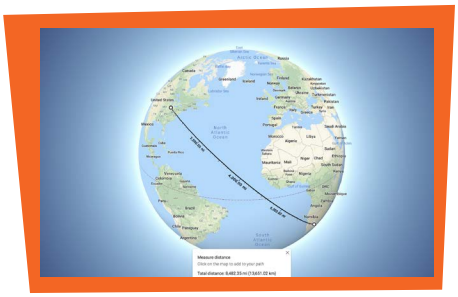
Show kids the Design Board described in the Prepare Ahead of Time section. **Point out the 4 areas:** Food, Water, Energy, and Environment. **Ask kids to tape** their invention sketches in the category where they belong.

Display the Design Board in the room. (Optional: You can also use the board to collect design sketches kids create in Sessions 3, 4, and 5. It is an easy way to store the ideas for the Partner Exchange.)

Take photos of the Design Board to share with your partner group!

FIND OUT ABOUT YOUR PARTNER CLUB! (20 minutes)

Introduce kids to their partner club! Share:



- **The map** you printed from Google Maps that shows both club locations. Tell them the number of hours it would take to fly from one location to the other. Or, use one of the *World Map* handouts and draw a line between locations.
- **The time difference:** Tell kids what the current time is in both places.
- ***World Map* handout:** Give each kid a copy that they can take home. (Optional: Ask them to color in both countries and draw a line connecting them.)
- **Interesting facts:** Tell kids some surprising things you learned about your partner club when you talked to your partner club leader or from the *Leader Exchange* forms.

Start the Partner Club Exchange


PARTNER CLUB EXCHANGE

Help your partner club get to know you a little better! What are some things that you would like to tell them about you, your community, and your country?

INFORMATION ABOUT YOU!

Name:

Nickname:

One thing I like doing . . .

One thing interesting about me . . .

My favorite music/movies/hobbies/games . . .

One thing I like about my country . . .

QUESTIONS FOR YOUR PARTNER CLUB!

Now it's your chance to find out more about your partner club! Ask the kids something you'd like to know about their . . .

School:

Community:
(where they live)

Country:

Or ask another question:

- **Give a *Partner Club Exchange* form** to each club member. **Explain to kids:** *Tell your partner club about yourself and ask questions on this form. I will send the forms to your partner club after our meeting.*
- **Ask kids to fill out the forms.** Ask them to tell their partner club members something about themselves, their lives, their country, and their community. Discuss with kids the questions they want to ask before they write the questions down on the form.
- **Take photos:** Ask each club member to pose for a photo. (Later, you will attach the photos to their forms.)
- (optional) **Take videos:** Create a short 1- to 2-minute video in which kids introduce themselves. (Check with your partner leader ahead of time to make sure the videos you send can be watched.)
- **If you do not have much time:** Take a group photo, ask kids the questions from the *Partner Club Exchange* form as a group, and write/type up the answers yourself.
- **If kids cannot finish** the *Partner Club Exchange* forms and take photos in this session, allow the club to complete them at the beginning of Session 2.

Ask kids to clean up.

- **Collect the *Partner Club Exchange* forms.**
- **Resupply your Recycled Materials Box** with the usable leftover paper and materials from the session.
- **Give each kid a sticker for their membership cards. Collect the cards** or ask kids to store them.
- Tell kids that next week they will do their **first engineering and invention challenge.**

AFTER THE SESSION:

SEND PARTNER CLUB EXCHANGE

- When the session is over, gather the *Partner Club Exchange* forms from your members, print and attach their photos, scan the pages, and send them to your partner club. Your partner club leader will do the same.
- You can also create a Word document summarizing everyone's responses.
- Another option: create a short 1- to 2-minute video in which kids introduce themselves. (Check with your partner leader to make sure they can watch the videos you send.)

WORLD MAP

DESIGN squad Global

PBS KIDS

MAJOR FUNDING The Lemelson Foundation

ADDITIONAL FUNDING NCEES advancing licensure for engineers and surveyors | UL INNOVATIVE EDUCATION AWARD

Major funding is from the Lemelson Foundation. Project funding is provided by United Engineering Foundation (UEF), the National Council of Examiners for Engineering and Surveying (NCEES), and the UL Innovative Education Award.

WGBH Design Squad Global is produced by WGBH Boston.

World Map: Adobe Stock/Pyty

DESIGN squad Global HANDOUT

MEMBERSHIP CARDS

To make membership cards, print this page (in color, if possible). Then cut out the cards and fold them in half on the dotted line. Make holes where shown and attach a string to each card so kids can wear them during club meetings.

After every engineering challenge or activity, give each kid a sticker to put on the grid on the back of each card. Membership cards can get lost easily. Pick a place where kids can find them at the start of each session and return them when it is over.

DESIGN squad Global

Club Member

Session 1 Completed	Session 5 Completed
Session 2 Completed	Session 6 Completed
Session 3 Completed	
Session 4 Completed	

DESIGN squad Global

Club Member

Session 1 Completed	Session 5 Completed
Session 2 Completed	Session 6 Completed
Session 3 Completed	
Session 4 Completed	

PBS KIDS

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WGBH Design Squad Global is produced by WGBH Boston.

DESIGN squad Global HANDOUT

PARTNER CLUB EXCHANGE

Help your partner club get to know you a little better! What are some things that you would like to tell them about you, your community, and your country?

INFORMATION ABOUT YOU!

Attach or insert photo here if available

Name:

Nickname:

One thing I like doing . . .

One thing interesting about me . . .

My favorite music/movies/hobbies/games . . .

One thing I like about my country . . .

QUESTIONS FOR YOUR PARTNER CLUB!

Now it's your chance to learn more about your partner club! Ask the kids something you'd like to know about their . . .

School:

Community:
(where they live)

Country:

Or ask another question:

PBS KIDS

MAJOR FUNDING The Lemelson Foundation ADDITIONAL FUNDING NCEES INNOVATIVE EDUCATION AWARD

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ASSESSMENT (OPTIONAL)

In the first and last sessions of the guide, you can ask kids a few questions about engineering, invention, and their experiences with their partner club. By comparing their "before" and "after" responses, you'll see how much they've progressed in their understanding of engineering and in their development of global competency.

FIRST SESSION QUESTIONS:

1. What do you think engineers do?

2. What is an inventor? How is an inventor different from an engineer?

3. Could you see yourself working as a professional inventor or inventor in the future? If so, what kinds of problems would you like to try to fix?

4. Now that you've been introduced to your partner club, what do you think the kids will be like?

LAST SESSION QUESTIONS

1. Now that you have done some engineering and inventing yourself, how would you describe what they are? Complete these sentences: "I used to think engineering and invention were. . .. Now I think they are. . ."

2. Could you see yourself becoming an engineer or inventor in the future? If so, what kinds of problems would you like to work on?

3. Now that you have interacted with the kids in your partner club, what surprised you about them? Complete these sentences: "I used to think . . . about my partners. Now I think . . ."

MAJOR FUNDING The Lemelson Foundation ADDITIONAL FUNDING NCEES INNOVATIVE EDUCATION AWARD

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SESSION 2: THE FLIGHT TEST CHALLENGE

(60 MINUTES)

OVERVIEW

THE FLIGHT TEST CHALLENGE!

(60 minutes)

Design an airplane, using paper and a spoon, that reduces drag and flies fast!

SESSION GOALS

ENGINEERING AND INVENTION

- Kids see engineering and invention as creative problem-solving.
- Kids learn about the design process and apply it to their first hands-on activity.
- Kids learn **key science concepts**:

  Force — A push or pull.

  Drag — The force of wind resistance pushing on an object.

ENVIRONMENTAL SUSTAINABILITY

- Kids discuss the problems of drag in airplane design. Too much drag causes the airplane to use too much fuel.
- Kids learn how improving the design of airplane wings and bodies can reduce energy use.

GLOBAL COMPETENCE

- Kids take pictures during the activity to share with their partner club.

PREPARE AHEAD OF TIME (about 60 minutes)

1. **Read through these instructions** and make notes.
2. **Divide up the tasks** with your co-leader/assistant.
3. **Get a camera/phone** for capturing photos and videos. Take photos and (optional) videos of kids doing the activities during this session, as well as Sessions 3, 4, and 5. You will send pictures and/or videos to your partner club at the end of Session 5. Your partner club will do the same.

   Photo/Video Guidelines

   - Be sure to take photos of club members as well as the activities!
   - Find out if your partner club leader can show videos at their club. Keep videos short (1 or 2 minutes at the most).
   - Remove the duplicate and boring photos after each session. If you organize your photos each time, it will take less time for kids to agree on the photos they want to send to their partner club.

4. **Check to see if you have received the *Partner Club Exchange* forms from** your partner club leader. You partner club should have sent them after the last session, and you will share them in the next session, Session 3: The Sneaker Challenge.

   Call or e-mail immediately if you have not received a response yet. Kids will be eager to hear from their partners! (And if you have not sent your club's form—do it now!)

5. **Gather materials.**

   For preparing the room before the session:

   - ☐ thread that is smooth—20 feet (6 meters) long (Note: rough cotton or sisal string does not allow the vehicles to slide. Surprisingly, nylon fishing line slows vehicles as well.)
   - ☐ 1 metal spoon per club member (The smaller, teaspoon size, works best. Spoons should not be too heavy.)
   - ☐ masking tape or clear tape
   - ☐ 2 paper clips per kid (The larger-sized paper clips work best.)

   For the demonstration:

   - ☐ 1 paper airplane that you make ahead of time
   - ☐ 1 unfolded sheet of scrap paper

   For each club member:

   - ☐ 3–5 sheets of letter size—8½ x 11 inches (20 x 28 centimeters)—paper, or similarly sized scrap paper, to make the airplanes

For the whole club:

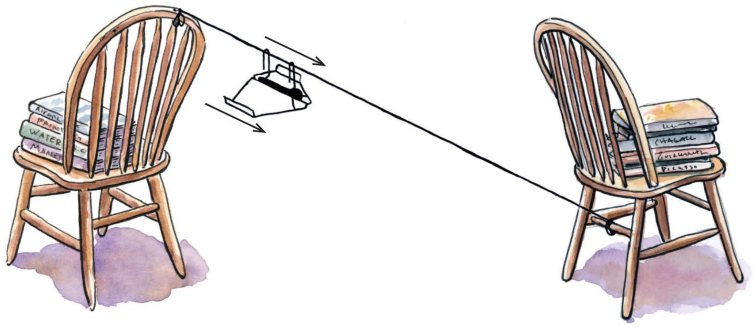
- ☐ 1 roll of masking tape or clear tape
- ☐ stopwatch, clock, or timing app on a phone
- ☐ pencil and paper for recording times

Note: If materials are unavailable, feel free to use substitutes. For instance, objects other than spoons can also give the airplanes the appropriate structure and weight. You will be able to judge what substitutes work best if you try the activity yourself before you do it with kids.

Kids will not need the club's Recycled Materials Box for this session, except for cleanup of scrap paper afterward.

6. **Set up a zipline** in the club meeting space before the session.

   A zipline is a rope or wire placed high in the air that people can slide down. You will create a small version, 10–20 feet (3–6 meters) long, for the airplanes to slide down.

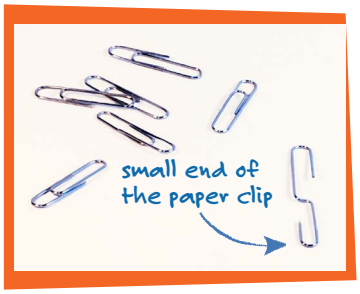


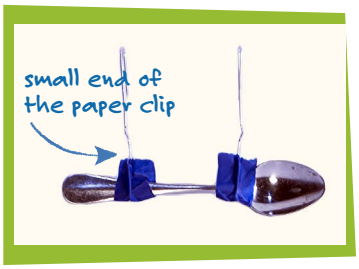
To make your zipline, **find a space in the room that is large enough**. A corner works well because it prevents kids from running behind the zipline.

- Attach the thread to a chair, post, stepladder, or other tall, solid object. (This end needs to be about 2–3 feet/60–90 centimeters higher than the lower end to allow the airplanes to slide down.) To keep this object from moving, you may have to add heavy objects, such as a stack of books.
- Attach the lower end to a heavy movable object, such as a stack of books, chair, or stool.
- Move one end of the zipline slowly backward to increase the tension on the thread until it is straight.

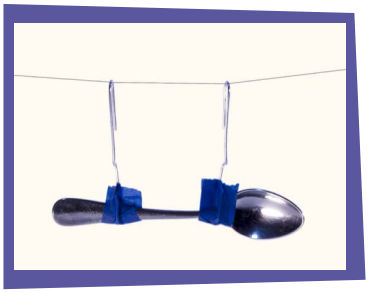
- Optional step, for safety: Add a second thread near your zipline and use tape to hang the poster, *Flight Test* (on page 61). This helps everyone see the zipline and not accidentally run into it.

7. **Prepare the spoons and paper clips.** The spoons give weight and structure to the airplanes. During the activity, kids will make the body and wings of the airplane out of paper and attach them to the spoons. They will then use the paper clips to attach the airplane/spoons to the zipline.
   - Bend 2 paper clips into an S shape for each spoon, so that they will work as hangers.
   - Put one paper clip near the eating end of each spoon and another near the handle end and make sure that the hooks are facing the same way. Use the smaller ends to hook around the spoon. Tape the clips onto the spoon.





   - Tape the paper clips in the same place on each spoon so that the weighting is equal.



   - **Test:** Hang the spoon on the zipline and let it travel all the way down. Does it slide smoothly?
     - If not, the paper clips may need to be bent further so that they hang at right angles to the thread.
     - The thread may be so loose that it sags: Tighten it by moving one end of the zipline farther back.
     - As a guideline: A spoon should take around 3 seconds to travel down a 10-foot (3-meter) line and 5 seconds down a 20-foot (6-meter) line.

8. (Optional) **Display the Design Board** that you created in Session 1 and use the board to save kids' sketches.

9. **Print the handouts**.

For each club member:

☐ **Handout:** *Designer's Notebook—Airplanes* on page 59

For the whole club:

☐ **Poster:** *The Design Process* on page 60. You will use this in every session. You can print copies in letter size—8½ x 11 inches (21.6 x 27.9 centimeters)—or in poster size—24 x 26 inches (61 x 91.5 centimeters). The same graphic will print on both sizes clearly. To make the large poster, take the file to a print or copy shop.

More information on the design process is on page 33.

☐ (optional) **Poster:** *Flight Test* on page 61 (This poster helps everyone see the zipline and not accidentally run into it.)

LEAD THE SESSION (60 minutes)

START THE FLIGHT TEST CHALLENGE! (60 minutes)

Tell club members they are going to do their first engineering and invention challenge! **Show them *The Design Process* poster** and point out the steps. You could tell them that people use this process to get better at something:

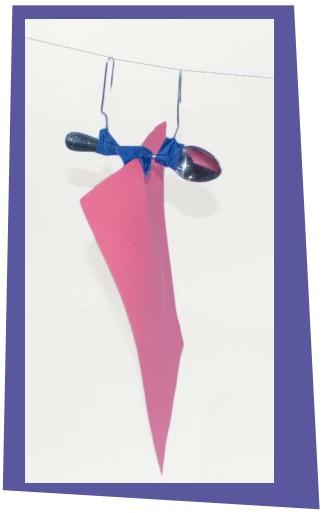
- In sports, athletes usually start a new year with a pre-season game. Then they practice what they need to improve, test their skills again in the next game, and practice some more. That's how they get better!
- Musicians often play a song poorly at first. But they figure out what they need to work on and practice it until it sounds good!
- In the same way, engineers and inventors usually design something, test it, and redesign it to fix any problems. They may repeat these steps many times.

Define the Need (20 minutes)

Tell kids they will use the design process to design a better paper airplane. Ask what they know about airplanes:

- *What makes airplanes fly?* (If kids are unsure, say: engines, wings, air, fuel. Some kids may know the concept of lift, one force that holds an airplane in the air. This activity does not focus on lift, but instead has kids learn about the forces that push an airplane forward and back.)

Explain one problem with airplanes: The size and shape of some planes make them use a lot of fuel to fly. Wasting fuel is not good for the environment.



Demonstrate and test a "spoon airplane" with lots of air resistance or drag.

- Attach a flat sheet of paper to one of the spoons. It is best if the wide side of the paper faces down the zip line (see photo). That way you get maximum air resistance (drag).

Test the spoon airplane:

- **Give one club member a piece of paper and pencil to record the time.**
- **Choose another kid to use the stopwatch** to time the airplane's flight. Ask this club member to put the spoon airplane at the top of the zipline and release it when ready.
- **Ask the timer to announce the result to the group**.

Discuss with kids: *Do you think the spoon airplane went fast? Why or why not?* Allow a few minutes for kids to discuss their observations, then ask them to share their thinking with the group.

- **Listen to ideas** that kids share.
- **Add the following** if not mentioned: The shape of the piece of paper creates air resistance or **drag** on the spoon airplane.
- **Define drag:** *Drag is the force of the air pushing against an object.*

Discuss the concept of drag:

- *Have you ridden your bike or run against the wind on a very windy day? Who remembers doing this and what was it like?*
- *You probably felt a push or pull. You felt the force of air resistance or drag.*
- *If you run sideways against the wind, does that feel different? Why do you think that is?* (When you run sideways, drag is less because your body is not as wide.)
- *What pushes a real airplane forward, making it fly fast?* (The force supplied by the engines, fuel used by the engines.)
- *When an airplane is flying in the sky, what pushes against the airplane's wings and body to slow it down?* (The force of drag.)
- *What is the problem with drag?*
  - To overcome the drag, the airplane needs to burn more fuel to keep going at the same speed.
  - Airplanes use a type of fossil fuel. Wasting it is bad for the environment.
- *Can you think of another vehicle whose shape creates a lot of drag?* (A large cargo truck with a flat front or a boxy car.)

Tell kids that in the next step, they will test for drag on their own spoon airplanes.

Brainstorm, Design, and Build (10 minutes)

Explain the activity:

Give kids the handout: ***Designer's Notebook—Airplanes.***

- *Your challenge is to build a paper airplane that moves through the air fast.*
- *You are going to test your airplane on the zipline and time how fast it goes from start to finish.*
- *As you redesign and test, try to eliminate some of the drag so that your airplane can go faster.*
- *Brainstorm with each other about what kind of wing and body design would make a spoon airplane go as fast as possible.*

Give everyone the spoons and sheets of paper. Tell kids to make the spoons into airplanes. **There are a few things to keep in mind:**

- *Your design should look like an airplane with wings and a body.*
- *To build your airplane, you have to use the full sheet of paper.*
- *You cannot attach anything to make your airplane heavier.*
- *The paper clips need to hook to the zipline. No other parts of your airplane should touch the zipline. That would slow your airplane down.*

Fun Facts:

- **What is the biggest airplane?** The Airbus A380 holds 850 passengers and measures 239 feet (73 meters).
- **What is the smallest plane?** The Bumble Bee II holds 1 passenger and measures 9 feet (2.7 meters).
- **Why don't inventors use solar panels to power airplanes?** They do in Switzerland. The airplane is called the Solar Impulse. It has flown in tests between many cities and countries but has not been used to carry travelers or cargo because it has to remain very lightweight to fly.

Test, Evaluate, and Redesign (30 minutes)

TEST

Ask club members to work in pairs for the test flights on the zipline:

- *One kid will be the timer, timing and recording the flight of the spoon airplane from top to bottom with the stopwatch.*
- *Another kid will release his or her airplane at the top of the zipline when the timer is ready.*
- *Kids should then switch roles and time and record the speed of the other airplane.*
- *After that, kids should run a second test for both airplanes.*
- *Select the fastest time and write it down.*

Remember to **take photos** to share with your partner club!

Notes: It ruins the test if kids push their airplanes down the thread. Tell them to let go of their airplanes gently! If any airplanes do not travel smoothly down the zipline, check the tension in the thread first. If the zipline is not the problem, it is probably an issue with the

design of the plane. Remind the group that the design process is all about learning from problems and trying again. Ask kids to redesign their planes to travel smoothly down the zipline.

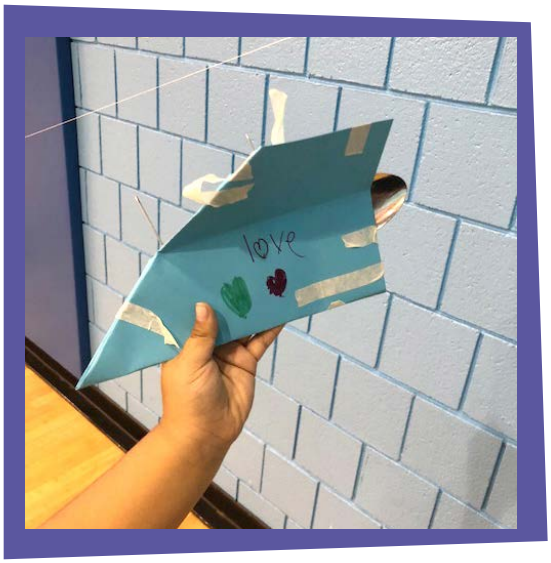
EVALUATE

Gather kids together to compare their designs and **discuss** why they think one worked better than another:

- *Did your spoon airplane go faster than the spoon with the flat piece of paper? Why?* (The one with the flat paper had a lot of drag.)
- *Which club member's spoon airplane went the fastest? What about its shape made it go the fastest?*
- *What things affected the speed of all the spoon airplanes?* (Drag, weight, friction on the paper clips.)

Tell kids you will do a quick demonstration using the airplane made out of a flat piece of paper. From shoulder height, drop a flat piece of paper and a paper airplane, without a spoon, that you made ahead of time. Which one hits the ground first?

Ask and discuss:



- *Why does the airplane have less drag than the paper?* (If kids are unsure, say: *The airplane's body is not as wide as the flat page, so the air does not push on it with as much force.)*
- *How could you change your design to make your airplane fly faster and beat its previous time?* (Fold the airplane wings closer to the body.)

Discuss the shapes of the real airplanes in the images on the handout:

- *What is different about the airplanes on the handout from some other airplanes you have seen?*

  If kids are unsure, suggest some possibilities:
  - They are thinner and sleeker.
  - They have engines in the back and small wings—"winglets"—on the ends of their wings.
- *Why do engineers and inventors create new airplane wings and bodies?*
- *What are some other fast objects or animals?* (If kids are unsure, say: *shark, football, rocket.*) *What are their shapes?*

REDESIGN

Suggest ways to redesign the spoon airplanes:

- *Take another piece of paper and create an improved airplane shape that has less drag.*
- *Think about the shape of the airplane and any parts that might push against the air as it goes down the zipline.*

- *Then test it. That is how engineers and inventors make their designs better—by testing to learn what is working and not working, so that they can use what they learn to redesign their product or invention.*

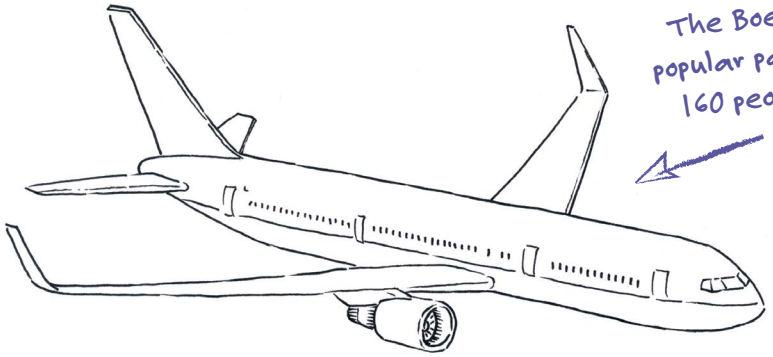
Ask kids to clean up.

- **Let kids keep their spoon airplanes and the spoons, if possible.**
- **Resupply your Recycled Materials Box** with the usable leftover paper and materials from the session.
- **Give each kid a sticker for their membership card. Collect the cards** or ask kids to store them.

DESIGN squad Global HANDOUT

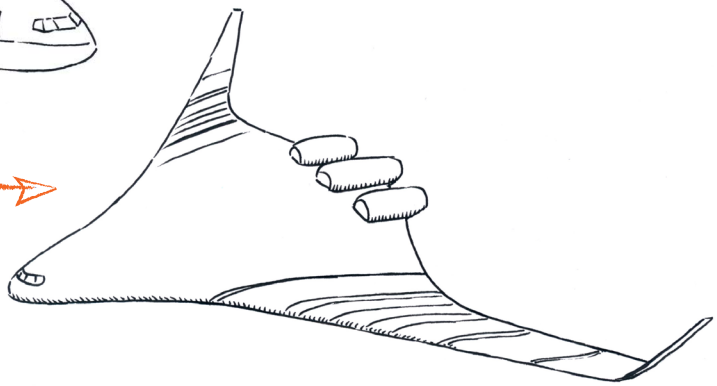
Designer's Notebook

AIRPLANES

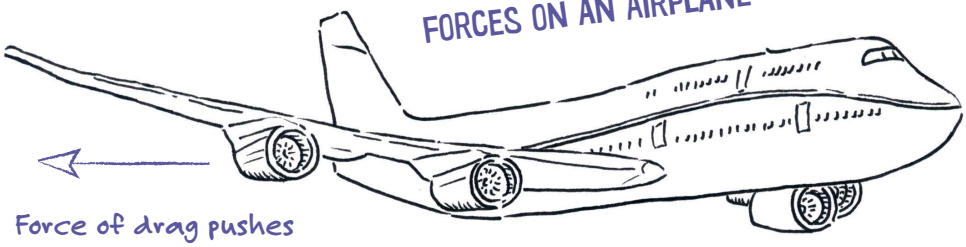


The Boeing 737-800 is one of the most popular passenger airplanes. It can carry 160 people and uses 850 gallons (3,200 liters) of fuel per hour.

The National Aeronautics and Space Administration in the US has created a prototype called the "Blended Wing Body." The plane should lower drag and improve fuel efficiency for passenger flights in the future.



FORCES ON AN AIRPLANE



Force of drag pushes airplane back

Force of engines pull airplane forward

AIRPLANE TEST TIMES

	Seconds
Test 1	
After Redesign	
Test 2	
Test 3	

PBS KIDS

MAJOR FUNDING The Lemelson Foundation ADDITIONAL FUNDING NCEES INNOVATIVE EDUCATION AWARD

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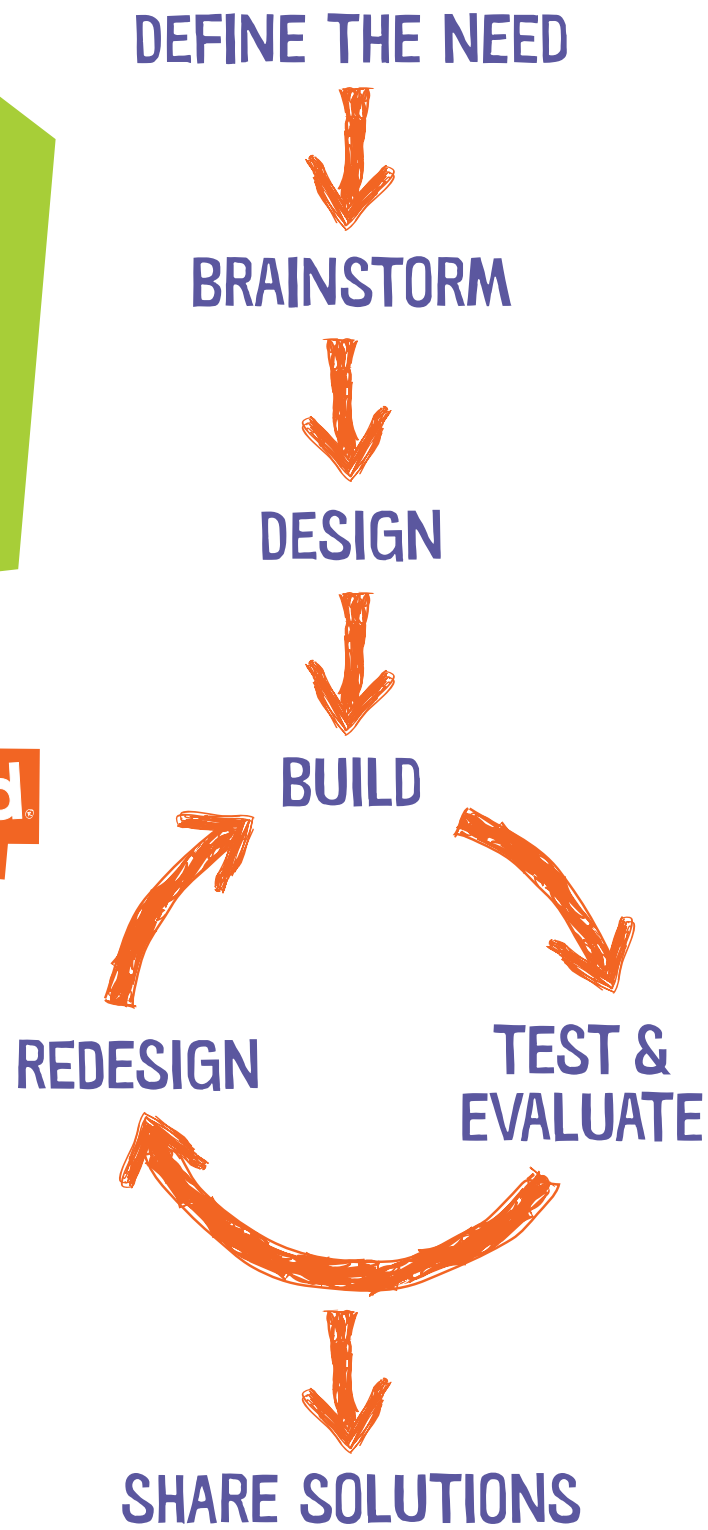
WGBH Design Squad Global is produced by WGBH Boston.

THE DESIGN PROCESS

Used by engineers, inventors, and other problem solvers, the design process is a series of steps that help people think creatively and come up with solutions.

DESIGN squad Global



PBS KIDS

MAJOR FUNDING The Lemelson Foundation

ADDITIONAL FUNDING NCEES advancing licensure for engineers and surveyors | UL INNOVATIVE EDUCATION AWARD

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DESIGN squad Global

FLIGHT TEST

MAJOR FUNDING The Lemelson Foundation improving lives through invention
ADDITIONAL FUNDING NCEES advancing licensure for engineers and surveyors
INNOVATIVE EDUCATION AWARD POWERING A SUSTAINABLE TOMORROW

Major funding is from the Lemelson Foundation. Project funding is provided by United Engineering Foundation (UEF), the National Council of Examiners for Engineering and Surveying (NCEES), and the UL Innovative Education Award.

Design Squad Global is produced by WGBH Boston.

SESSION 3: THE SNEAKER CHALLENGE

(60 MINUTES)

OVERVIEW

PARTNER CLUB EXCHANGE
(15 minutes)

Hear what your partner club sent about themselves!

THE SNEAKER CHALLENGE!
(45 minutes)

Design sneakers that do not harm the environment when created or thrown away.

AFTER THE SESSION:
SEND THE KIDS' RESPONSES TO YOUR PARTNER CLUB'S QUESTIONS

Reply to your partner club's questions.

SESSION GOALS

ENGINEERING AND INVENTION

- Kids strengthen their understanding of the design process and discover the importance of the brainstorm and design steps.
- Kids explore the physics of forces on a person's feet while running and playing.
- Kids learn **key science concepts:**

  Force — A push or pull.

  Life cycle — The story of a material from how the material is made to where it goes when it is thrown away.

  Biodegradable — Breaks into small pieces that do not harm the environment after it is thrown away.

ENVIRONMENTAL SUSTAINABILITY

- Kids evaluate the materials that are usually used to make athletic shoes and consider new materials for cost, comfort, and sustainability.
- Kids think about the life cycles of various shoe materials and consider their benefits and problems.

GLOBAL COMPETENCE

- Kids experience the excitement of learning about people and places from other countries and cultures.

PREPARE AHEAD OF TIME (about 60 minutes)

1. **Read through these instructions** and make notes.
2. **Divide up the tasks** with your co-leader.
3. **Do the activity** yourself or with your co-leader.
4. Print out or gather the *Partner Club Exchange* forms your partner club sent you. If you have not received the forms, text or email your partner club leader.
5. **Gather materials.**

For each club member:

- ☐ 1–2 sheets of scrap paper for drawing
- ☐ pencil

For each pair of kids or team:

- ☐ scrap of cardboard about 12 inches by 6 inches (30 centimeters by 15 centimeters) or larger
- ☐ duct tape
- ☐ scissors

For the whole club:

- ☐ **Prepare your Recycled Materials Box.** Add items that could make good cushioning material. The items could be natural materials, such as bamboo, straw, grass, and tree bark. The items could be materials created by people, such as bubble wrap, rubber bands, tennis or rubber balls, sponges, styrofoam, food packaging, plastic tubing, balloons, plastic shopping bags, old clothing, and binder clips (to be used as springs). After completing the session, save usable leftover materials in this box.
- ☐ 1 plastic water or soda bottle, any size
- ☐ *Partner Club Exchange* forms you received from your partner clubs
- ☐ (optional) old athletic shoe (that you are willing to destroy)
- ☐ (optional) razor, utility knife, or other very sharp knife, for educator use only
- ☐ (optional) thick cloth or towel, or thick glove

6. (optional) **Prepare a demonstration** of an athletic shoe. Kids love to see how shoes are designed by looking at the inside of a shoe. You can easily cut a shoe in half if you work slowly and with caution.
   - Turn the athletic shoe over so that the sole is facing you.
   - Hold the shoe steady with one hand. Protect this hand with the cloth, towel, or glove.

- Make many small cuts down the length of the sole with the razor or knife. Press down lightly many times; this will lower the risk of slipping and causing an injury.
- Gently and carefully cut through the upper part of the shoe. Pull the shoe halves apart.

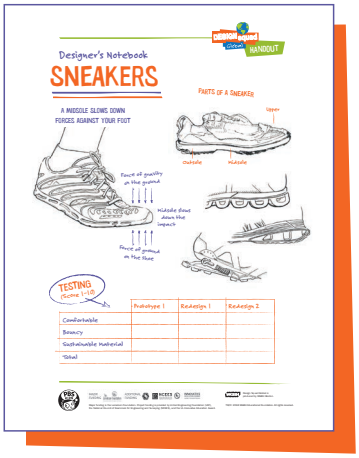
7. (optional) **Display the Design Board** that you created in Session 1 and use the board to save kids' sketches.
8. Print the handouts.

For each club member:

☐ **Handout:** *Designer's Notebook—Sneakers* on page 71

For the whole club:

☐ **Poster:** *The Design Process* on page 60 (if you have not already printed it for the previous session)



LEAD THE SESSION (60 minutes)

ASK KIDS TO READ THE RESPONSES FROM THEIR PARTNER CLUB (15 minutes)

Read the responses:

Ask a volunteer to read aloud your questions and your partner club's responses. Gather the *Partner Club Exchange* forms you received.

Ask:

- *What do you have in common with the kids at your partner club?*
- *How are you the kids at your partner club different?*
- *Did any of their answers surprise you? Why were those answers surprising?*

Hear the new questions:

Explain to kids that their partner club asked them questions. Ask a volunteer to read them. After each question, allow kids time to discuss and respond. Write down their responses. You will send their responses to your partner club after the session.

Afterward, ask: *What questions do you want to ask your partner club members now?*

START THE SNEAKER CHALLENGE! (45 minutes)

Tell kids:

- *Your challenge is to design sneakers* (also called athletic shoes, trainers, tennis shoes, kicks, and running shoes for different countries and people).
- *The goal is to invent a new kind of sneaker that would feel bouncy when you walk like most sneakers do. But, unlike most sneakers, it will be made from materials that do not harm the environment.*

Show *The Design Process* poster and go over the steps with kids. Tell them they will start with the first step:

Define the Need (5 minutes)

Ask: *Who wears sneakers? For what activities?*

Pass around the demonstration sneaker that you cut and ask kids to look at the handout, *Designer's Notebook—Sneakers.* **Ask:** *What are the different parts of a sneaker? What do the parts do?*

- The "upper" protects your foot from scrapes caused by rocks, sticks, and other objects.
- The "outsole" grips the floor or ground so you can stop or turn quickly.
- The "midsole" makes your foot feel better when it hits the ground hard.

Ask kids to look at the image on the handout about the forces against your foot. Explain how shoes protect your feet:

- *When you run and jump, your foot hits the ground with a force.*
- *Force is a push or pull.*
- *The ground pushes back on your foot with the same force. (Ouch!)*
- *The pressure your foot feels is the force of the ground on your foot.*

Discuss the science of sneaker midsoles:

- *Running fast and jumping high do not usually hurt your feet or legs when you are wearing sneakers. Why?*

  If kids seem unsure, explain:

  - *A sneaker's foam midsole is soft.*
  - *When you jump, the midsole comes between your foot and the ground.*
  - *The midsole increases the time it takes for your foot and the ground to hit.*
  - *Impacts are all about time. What if your friend poked your arm very quickly—it would hurt! But if your friend used the same force over 10 minutes, it would not hurt (it would just be a little weird.)*
  - *When it takes longer for two things to hit together, the impact doesn't hurt as much. Sneaker midsoles slow the impacts on our feet.*

Hold the plastic bottle. Ask kids: *Sneakers do a good job at protecting our feet, but what are the midsoles usually made from?* Listen to kids' answers and add:

- *Both the sneaker midsole and this bottle are plastic, which can be hard on the earth.*
- *Plastic takes over 1,000 years to break apart naturally.*
- *It creates pollution on land and in the ocean.*

Talk with kids about environmentally sustainable designs for shoes:

- *Plastic midsoles have other problems in the* ***life cycle*** *of the material. What's a life cycle?*
- If kids seem unsure, tell them: *The life cycle of a material is the story of the material from how it is made to where it goes when it is no longer used.*
- *When we design our own sneakers in a minute, we are going to think about the life cycle of the materials we use.*
- *Let's talk about an example of a life cycle:*

Hold up the demonstration sneaker. Say and ask:

- *Everything has a life cycle. What is the midsole made from? What is the material?* (Plastic!)
- *Where did the plastic come from?* (The plastic in it is made from fossil fuels, like oil and natural gas, that companies pump from the ground.)

- *What happens next?* (The oil is made into plastic and the plastic is made into a sneaker. Energy from fossil fuels powers the factory that makes millions of sneakers.)
- *Then where do the sneakers go?* (The sneakers travel all over the world to customers, usually on a big ship. The ships burn fossil fuels to go thousands of miles.)
- *What happens after people buy it?*
  - People play and take part in sports with sneakers.
  - Then they throw sneakers away when the sneakers are no longer useful.
  - Unlike a plastic bottle, the plastic in midsoles cannot be recycled.

Brainstorm and Design (10 minutes)

BRAINSTORM

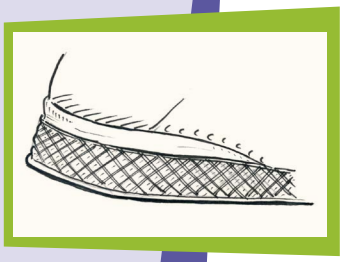
Show the materials to the club, including the ones in the Recycled Materials Box. **Ask the whole group to brainstorm** how to make sneakers less harmful. Discuss how engineers and inventors design sneakers:

- *Engineers and inventors consider both the benefits and the problems of different materials.*
- *For shoes, engineers and inventors need to consider the benefits and the problems of a material's cost, safety, durability, appearance, and environmental sustainability.*
- *What materials could you use to make a bouncy midsole that is better for the environment than plastic foam?*
- *What are ways that you could recycle materials in your design?*
- *What are ways you could use materials that are **biodegradable** when the shoe is worn out?* (Biodegradable materials break into small pieces that don't harm the environment after they are thrown away.)
- *What materials would last longer than plastic foam? By using a material that lasts longer you could lower the amount of waste in landfills.*

Building with Structure

Some sneaker companies make their midsoles with a honeycomb pattern, like in a beehive, or with small squares. This kind of design uses less material but provides the same bounciness as solid midsoles. And it feels good on your feet!

Ask kids to look at the inside layers of a piece of cardboard—it has a pattern—like triangles—to make the cardboard strong.



DESIGN

- **Give everyone drawing paper and pencils. Ask kids to work independently** to draw their designs. **Ask them to label the materials** using arrows to show where they would use plastic, metal, or natural materials. Tell them to consider testing their materials before they use them. For example, try jumping on the material to see how bouncy it is.
- Think about how your design could be environmentally sustainable.
  - *Where does the material come from?*
  - *Can the material be recycled?*
  - *Is the material biodegradable?*
  - *Could you use a material that lasts longer?*

Build (15 minutes)

Ask club members to work in pairs or small groups to build their sneakers. **Tell kids:**

- *Start by looking at the design drawings of your team members. You can take the best features and ideas of each team member to start your design.*
- *Build a prototype.*

Ask kids: What is a prototype?

If kids are unsure, discuss the idea of a prototype with them:

- *A prototype is a quick and simple model that lets engineers test whether their ideas will work.*
- ***Prototypes are often made with substitute materials** that create the look and feel of a final product.*
- ***Look over all the materials you have to work with before you begin.** If you do not see the material you would like to use, think about how the materials you have can work in your design.*

Tell kids: *First, trace a team member's foot on a scrap of cardboard.*

- *Cut along the outline of the foot with scissors.*
- *Use this cardboard scrap to start your shoe design.*

Remember to **take photos** to share with your partner group!

Give club members advice on building:

- *Focus on designing the midsole part of the shoe.* (Kids may not have time in the session to work on an upper or outsole.)
- *Build your prototype midsole using the cardboard scrap and any materials that are part of your design.*

Test and Evaluate (10 minutes)

Ask kids:

- *What is a good way to test your midsole?*

  If kids are unsure, suggest:

  - *Attach the prototype to your sock with tape and walk from one side of the club space to the other. Then carefully remove the prototype so you can redesign it.*
  - *Wear a prototype on one foot and a real sneaker on the other. Run and jump with both. Does one feel bouncier? Is your prototype comfortable?*

Fun Facts

- Inventors often test their shoes by placing them on a robot foot. Then the robot steps down thousands of times. If the sneakers survive this pounding, they are approved for sale.
- The special type of plastic used in shoe midsoles is the same used to make hot glue sticks!
- To make a single pair of sneakers, factories use the same amount of energy as running a microwave oven for 2 days straight.

Allow kids to discuss their shoes. **Ask:**

- *Was your sneaker bouncy? How could you change the design to add more cushioning?*
- *What problems did you have? How did you solve these problems?*
- *What would customers like about your shoe design? How could you make your design more comfortable?*
- *Can you describe the **life cycle** of the materials you used for your prototype? A life cycle describes how the material was made and where it goes.*
  - *Where would the factory get the materials to make your shoes?*
  - *What would happen to your midsoles when the sneakers are thrown away?*

Ask teams to score their prototypes using the handout.

Redesign (5 minutes)

Ask your club members to remove the parts that did not work on their sneakers and add new ones, or adjust the materials to make the shoe more bouncy and comfortable.

Ask kids to clean up.

- **Let teams keep their sneaker prototypes, if possible.** Or **ask teams to take their sneakers apart** and put the pieces in the Recycled Materials Box.
- **Resupply your Recycled Materials Box** with the usable leftover paper and materials from the session.
- **Ask kids to tape their sketches** to the Design Board, if you have one. If not, **save sketches** for the partner club exchange.
- **Give each kid a sticker** for their membership card. **Collect the cards** or **ask kids to store their cards.**

AFTER THE SESSION:

Send the Kids' Responses to the Partner Club's Questions

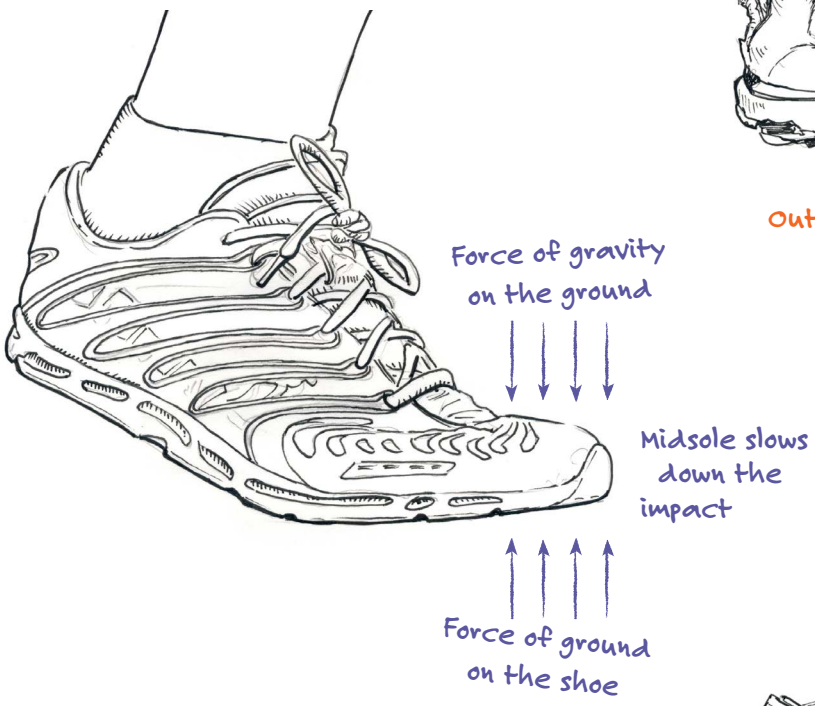
- Email your club members' answers to your partner club's questions (include your partner club's original questions). Also, email your club members your new questions.
- Your partner club leader will do the same.
- You will share your partner club's answers to your questions with your club members next week.

DESIGN squad Global HANDOUT

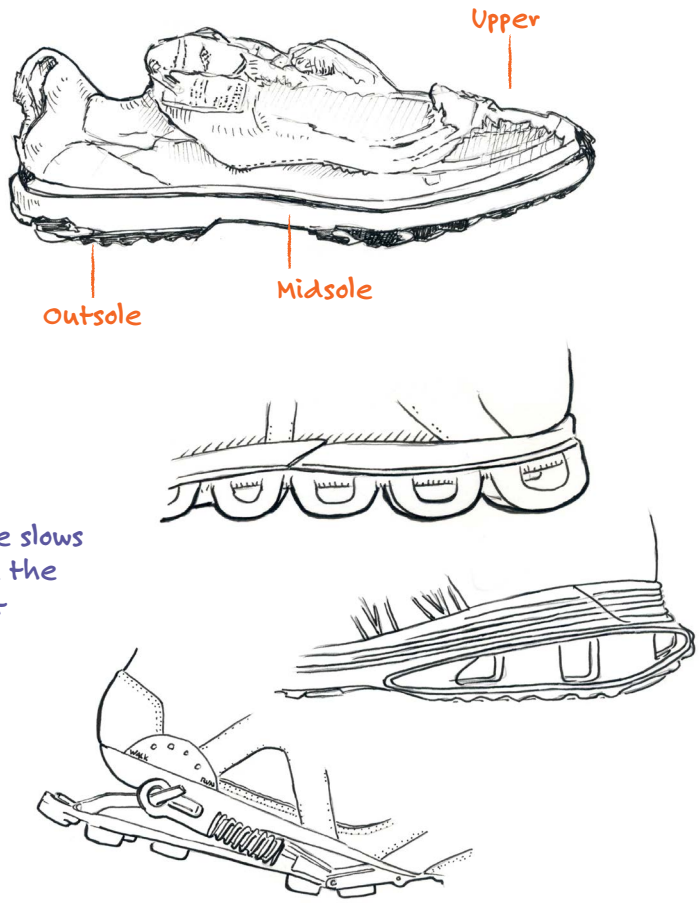
Designer's Notebook

SNEAKERS

A MIDSOLE SLOWS DOWN FORCES AGAINST YOUR FOOT



PARTS OF A SNEAKER



TESTING (Score 1-10)

	Prototype 1	Redesign 1	Redesign 2
Comfortable			
Bouncy			
Sustainable Material			
Total			

PBS KIDS

MAJOR FUNDING The Lemelson Foundation ADDITIONAL FUNDING NCEES INNOVATIVE EDUCATION AWARD

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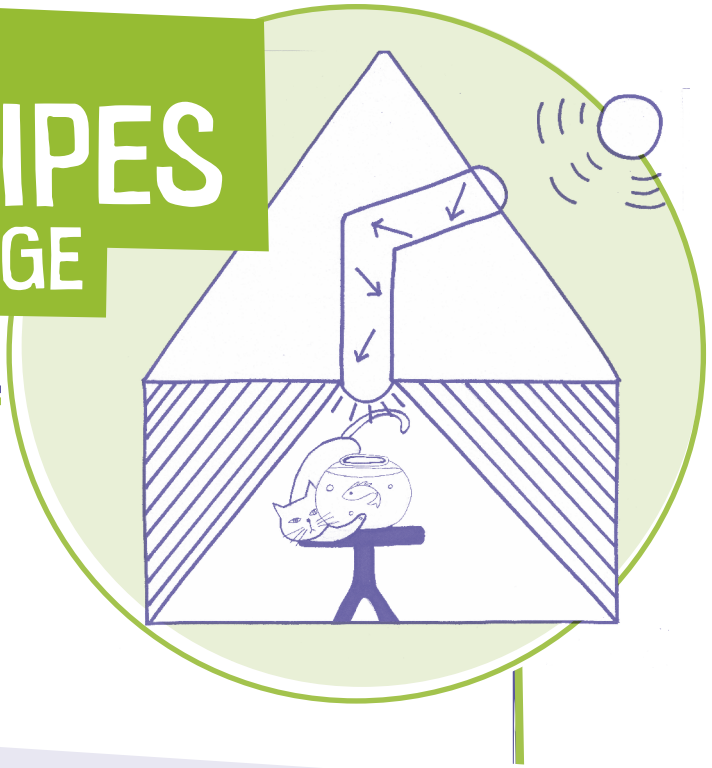
SESSION 4: THE LIGHT PIPES CHALLENGE

(60 MINUTES)



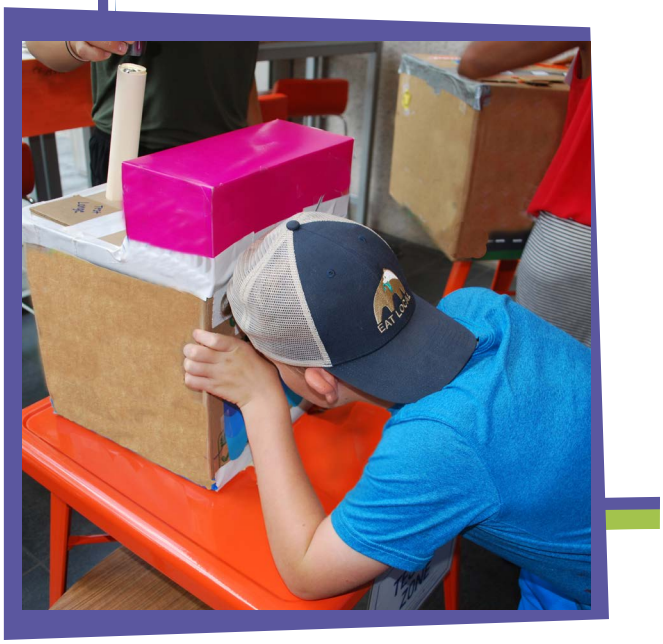
OVERVIEW

PARTNER CLUB EXCHANGE
(10 minutes)

Find out the answers to your questions about your partner club.

THE LIGHT PIPES CHALLENGE!
(50 minutes)

Design a way to bring sunlight into the prototype of a building.



SESSION GOALS

ENGINEERING AND INVENTION

- Kids strengthen their understanding of the design process and discover the importance of the test, evaluate, and redesign steps.
- Kids take on a real-world engineering and invention challenge by bringing natural light inside a prototype building.
- Kids test how much light their design brings into their cardboard building, by observation or using a phone app.
- Kids learn **key science concepts:**

  Light Rays — A model for showing light traveling in straight lines.

  Reflection — When light bounces off a shiny surface, such as a mirror.

  Lumen — A measurement that shows how much light there is.

ENVIRONMENTAL SUSTAINABILITY

- Kids learn ways to replace fossil fuel energy that would have been used to generate light.

GLOBAL COMPETENCE

- Kids learn more about their partner club members to find that they may have different perspectives, experiences, backgrounds, and beliefs—and that they also have things in common.

PREPARE AHEAD OF TIME (about 60 minutes)

1. **Read through these instructions** and make notes.
2. **Divide up tasks** with your co-leader/assistant.
3. **Do the engineering/invention activity** yourself or together with a co-leader/assistant.
4. **Check to see if you have received your partner club's responses** to your club's questions. Your partner club leader should have sent them after the last session.

   Call or e-mail immediately if you have not received a response yet. Kids will be eager to hear back from their partners! (And if you have not sent your **club**'s responses to your partners—do it now!
5. **Gather materials.**

For each club member:

- ☐ pencil
- ☐ 1–2 sheets of scrap paper (for kids to draw designs)

For each pair of kids or team:

- ☐ 1–2 sheets of reflective material: examples are aluminum foil or the silver inner lining of a clean, empty snack bag.
- ☐ 1–2 sheets of thick paper, such as poster board, card stock, or file folders.
- ☐ 1–2 small to medium-sized cardboard boxes
- ☐ scissors
- ☐ roll of masking tape or cloth-backed tape (such as duct tape)
- ☐ clear tape
- ☐ (optional) marbles, beads, or other pieces of plastic or glass

For the demonstration:

- ☐ 1 sheet of any reflective material (described above)
- ☐ 1 sheet of thick paper (described above)
- ☐ scissors
- ☐ clear tape

For the whole club:

- ☐ your club's Recycled Materials Box
- ☐ camera/phone for taking photos for the partner club exchange
- ☐ your partner club's responses
- ☐ (optional) mirror for demonstration of reflection

☐ (optional) phone app for testing light. Download an app to measure lumens of light. Examples are Lux Meter (free) on Android phones and Light Meter ($1.99) on iOS devices. Experiment before the session to understand how the app works and where to place the phone to measure the light.

6. **Create a demonstration.** Make a demonstration of a light pipe to show your club members.

- **First, cut the thick paper** into a rectangle. The paper will form the outside of the light pipe.

- **Put the reflective paper over the rectangle paper** and cut around it into the same size rectangle. Then, **tape them together.**

- **Roll the paper and reflective material** into a tube shape, so that the paper is on the outside. **Tape the outside of the tube** so it stays together.

- **Hold the tube up to your eye** and point it toward a light source to check the reflective surface inside the tube. Does the inside reflect light all the way around?

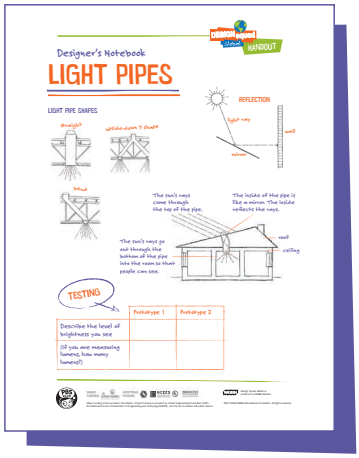
- (optional) **Tape a clear marble or large glass bead** to one end. (The marble or bead spreads light rays that go through the tube.)

7. **Watch the videos** you have taken, if any, during the sessions. Choose videos to show kids at the end of the session. Allow club members to decide which videos to show their partner club. If possible, make a new video during this session of kids describing their engineering and invention projects.

8. (optional) **Display the Design Board that you created in Session 1** and use the board to save kids' sketches.
9. **Print the handouts.**

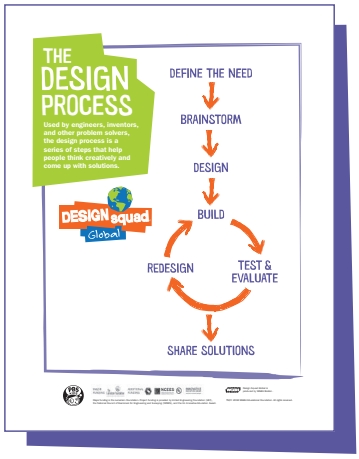
For each club member:

☐ **Handout:** *Designer's Notebook—Light Pipes* on page 83



For the whole club:

☐ **Poster:** *The Design Process* on page 60 (If you have not already printed it for the previous session.)



LEAD THE SESSION (60 minutes)

READ PARTNER CLUB RESPONSES (10 minutes)

Let kids know their partner club answered the questions they asked on the *Partner Club Exchange* form. Ask volunteers to **read aloud the questions and answers.** Afterward, **ask:**

- *Did any of your partner club members' answers to your questions surprise you? Why were the answers surprising?*
- *What do you have in common with your partner club members?*
- *What are some differences?*
- *Would you like to ask the club members other questions? What are they?*

START THE LIGHT PIPES CHALLENGE! (50 minutes)

Tell the club members: *you will be designing a "light pipe." (Also called a "light tube" or "solar tube.")*

Show *The Design Process* poster and go over the steps with kids. Tell them they will start with the first step:

Define the Need (5 minutes)

Ask and discuss:

- *How can you see inside a building if there are no windows?* (If kids are unsure, say: Lamps, lights, candles, glow sticks, other sources of light.)
- *In many parts of the world, families use kerosene, which comes from crude oil, to light their homes.*
- *What are the problems with these sources of light?* (Lamps and lights use electricity; candles use fire and are dangerous; kerosene makes smoke that is unhealthy to breathe; glow sticks cost a lot and do not last long.)

Show kids the demonstration you made of a light pipe in the Prepare Ahead of Time section and let kids pass the demonstration around.

Explain:

- *Many different types of buildings use light pipes to get natural light inside so that people can see.*
- *Light pipes use the science of reflection to direct light inside a building.*

Show kids a demonstration of reflection with a mirror

If you have a mirror, show them how light from the sun or an electric lamp reflects off the mirror:

- Hold the mirror in the path of sunlight or near a lamp.
- Reflect the light onto a wall so that the light rays show the mirror on the wall.

If you do not have a mirror, look at the picture of reflection on the handout with kids.

Explain:

- *The sun's light rays bounce off the mirror onto the wall.*
- *We call this reflection. Reflection is when light rays bounce off a shiny surface.*

Explain light rays to kids:

- *Sunlight travels to Earth in a straight line.*
- *A straight line is a ray, so we call the light a "light ray."*
- *The sun's light rays bounce off a mirror onto the wall. We call it reflection.*
- *Light pipes send sunlight inside a building using reflection.*
- *Next, we will check out how light pipes work.*

Give kids the handout: *Designer's Notebook—Light Pipes* and discuss the parts:

- The sun's rays come in through the top of the pipe.
- The inside of the pipe is like a mirror. The inside of the pipe reflects the rays.
- The sun's rays go out through the bottom of the pipe into the room, bringing natural light indoors and lighting up the room so people can see.

Ask and discuss:

- *What are the other ways to get sunlight into a room beside a light pipe?*

  If kids seem unsure, give examples:

  - Windows
  - Skylights, which are like windows on the ceiling

- *How would a light pipe help you get things done during the day?* (If kids are unsure, say: *A light pipe provides natural light indoors so that you can see better.*)
- *Do you think electric lights use a lot of energy?* (Yup. Lighting uses about 10 percent of the electricity in a home or more than a refrigerator.)
- *Do you see any advantages to using light pipes?*
  - Sunlight can be used indoors for free instead of paying for electricity for lights.
  - Some rooms cannot have windows or skylights because they are located in the middle of a building or are underground.
  - Natural light is nice looking.
  - Bringing natural light indoors connects people with the outdoors.
  - Light pipes can be designed to direct bright light where it is needed—such as putting it right over a chair so you can use the light to read.

- *Why do people want to save electricity?*
  - Electricity is often made by burning fossil fuels such as coal and natural gas.
  - Fossil fuels create pollution when they are burned.
  - Electricity is also expensive to create.

Fun Facts

- Light pipes were invented by ancient Egyptians.
- Today, they are often used in new houses, stores, and really big buildings.
- Some light pipes have a small mirror on the top. A motor moves the mirror around to follow the sun across the sky.
- Some have a small mirror that stays pointed at the moon all night. Instant moonlight indoors!

Brainstorm and Design (10 minutes)

BRAINSTORM

Ask the whole group to brainstorm ideas on how to bring sunlight inside buildings.
Ask kids:

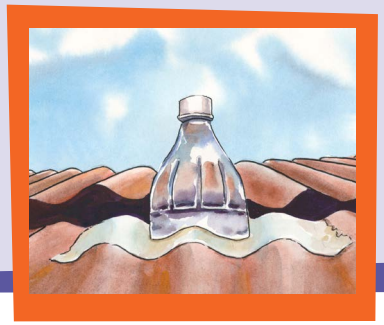
- *What kind of building could benefit from a light pipe?* (Examples could be a house, an apartment, or trailer, or a public building such as a school, library, farmhouse, or factory.)
- *What areas of these buildings usually need a lot of light?* (Kitchen counter, workshop, desk for doing homework.)

If you have glass beads or other materials to focus or spread out the light rays, **ask kids:**

- *How would a light pipe be useful if was designed to direct bright light where it is needed, focused in a bright circle?* (It could provide bright light so you could see a book well when reading, or see food in pots and pans well when cooking—or your invention when working on a Design Squad Global project!)
- *How would a light pipe be useful if its light spread all over a room?* (It could provide low light for activities such as eating dinner or watching TV.)

Liter of Light

In the Philippines, families without electricity started using plastic soda bottles as simple light pipes to bring sunlight into their homes. They cut holes in their roofs, filled bottles with water and bleach, and sealed the holes with glue. (The bleach keeps the water clear of algae and mold). The bottles are now used in Brazil, India, Kenya, and other countries around the world. Some families even use solar power (adding a small solar panel, battery, and LED bulb to the bottle) to make the bottle shine at night!



DESIGN

Give everyone drawing paper and pencils. Ask kids to work independently to draw their designs. Tell and ask them:

- *Draw any kind of building and show where light pipes would be useful.*
- *You can add a roof, rooms, even furniture to your drawing.*
- *When you draw your design, draw the light rays to show how the light travels from the sun, reflects in the light pipe, and then where it goes in your building.*
- *Do you remember what light rays are?*

  If kids are unsure, say:

  – *Light travels in a straight line.*

  – *A straight line is a ray, so we call the light a "light ray."*

Build (15 minutes)

Ask the group to form pairs or teams. Show the materials, especially the thick paper, reflective material, and cardboard boxes. If empty snack bags are one of the materials, you could say that snack bags cannot be recycled so this is a good way to reuse the material.
Tell kids:

- *Start by looking at the design drawings of your team members and choose a final design. You can take the best features and ideas of each team member for your prototype.*

Ask: *What is a prototype?*

If kids are unsure, discuss prototypes with them:

- *A prototype is a quick and simple model that lets engineers test whether their ideas will work.*
- **Prototypes are often made with substitute materials** *that create the look and feel of a final product.*
- *Does your design use a special material that we do not have, like metal or glass? How could you use the materials here to make something similar for your design?*

Explain the building steps:

- *Build a light pipe using the thick paper, reflective material, and clear tape. Later, you add your light pipe to a cardboard box to make a prototype of your building.*
- *Use your understanding of reflection to design the light pipe.*
- *Your light pipe can be narrow or wide. It can bend, or it can be straight. It can even split into an upside-down Y shape. You can also have more than one pipe going into a building.*
- *The light pipe has to be at least 6 inches (15 centimeters) long, but can be as tall as you would like.*
- (if you have optional marbles, beads, or pieces of plastic or glass) *Put pieces of plastic or glass on the end to focus the light or spread it around the building.*

Note: allow teams to design many different shapes for their light pipes. After you see that a team has made a light pipe, ask them to do a brief test by looking through one end of the light pipe at a light source, like the sun or a lamp. Teams should pass around the pipes to compare how well the different light pipes reflect the light.

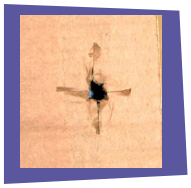
Some prototypes may not reflect much light inside. Remind the group that the design process is all about learning from failure and trying again. Inventors make mistakes all the time. Tell club members to study the problem and improve their designs.

When the kids are done with their light pipes, ask them to create a small building out of a cardboard box and tape. Ask kids to leave one wall of the building open to see inside. Then, ask them to add the pipes to the cardboard building to test their how well they light up the building.

When kids are ready to add their light pipes to their cardboard buildings, ask them: *How will you put your light pipe into your cardboard building?*

If kids seem unsure, show them one way:

- Ask kids to draw a circle where they want their light pipe.
- **The leader or assistant should cut a hole in this spot with scissors. (This step can be dangerous.)**



- First, punch a small hole with scissors.
- Use the scissors to cut small flaps outward from the hole in 3 or 4 directions. Then, to enlarge the hole, use your finger to fold down the flaps.

Remember to **take photos** to share with your partner club!

Test and Evaluate (10 minutes)

Ask kids to bring the **cardboard buildings into the sun or under a bright light bulb**. If you are using a light bulb, use the same bulb to test each design. If there are large gaps between the light pipe and the building, cover the gaps up with duct tape.

Tell and ask kids:

- *Look inside your building and see where the light rays appear. Are they bright?*
- *Can you think of ways to redesign your light pipe so it provides more reflection and adds more light inside your building?*

(optional) Interior Light Test

Help kids measure the number of lumens (a test of brightness) inside their prototypes. **Kids can take turns** using a camera phone with the app that measures lumens. (See the Prepare Ahead of Time section for the names of free apps to download.) :

- Tell kids that one way to test the brightness of a light pipe or light bulb is to scientific measurement of the "lumens." The number of lumens shows how bright a light looks to the human eye.
- Ask kids to put their building in a sunny spot. If using a light bulb, they should each put their buildings in the same spot, about 12 inches (30 centimeters) from the bulb, to measure the lumens.
- Show kids how to turn the app on and tell them to put the phone inside the building so that it measures the light from the light pipe.
- Lumens will range from 300 to 3,000, depending on a design's shape and reflective surface.

Ask and discuss:

- *How could you redesign your prototype? Could you put the light pipe in a different spot on your cardboard building?* (Note: if kids change the placement of their light pipe, tell them to cover their first hole with tape to block the light.)
- *Would a different reflective material inside you light pipe work better?*

- *Would the people who use your building enjoy the light? How could you change the placement to bring natural light to unexpected places?*
- *What if you add a second light pipe to your building? Make a new light pipe that is taller, shorter, thinner, or wider than your first pipe.*
- *What if your next light pipe design had a bend in it? How could you bend the light pipe to bring in light at different times of day—for example, in the early morning for breakfast, at midday for lunch or reading, or in the afternoon for snack time?*

Redesign (10 minutes)

If your group has more time, tell them to add the features from their designs to their cardboard buildings, such as a roof or furniture.

Ask kids to clean up:

- **Let team members keep their prototypes, if possible.**
- **Resupply your Recycled Materials Box** with useable leftover paper and other materials from the session.
- Ask kids to tape their **drawings to the Design Board**, if you have one. If not, save the drawings of their designs for the partner club exchange.
- **Give each kid a sticker for their membership card. Collect the cards** or ask kids to store them.

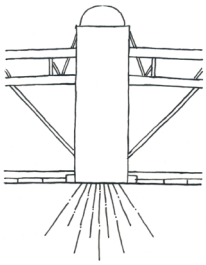
DESIGN squad Global HANDOUT

Designer's Notebook

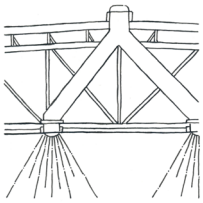
LIGHT PIPES

LIGHT PIPE SHAPES

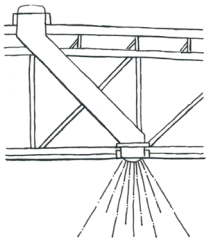
straight



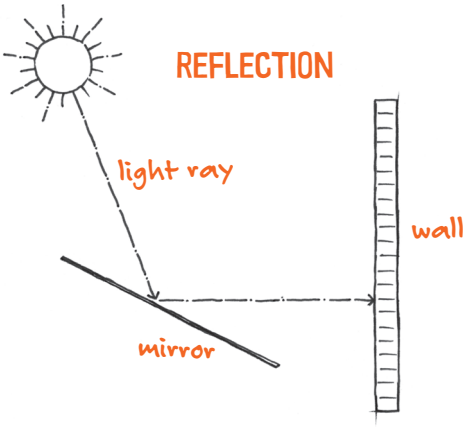
upside-down Y shape



bend



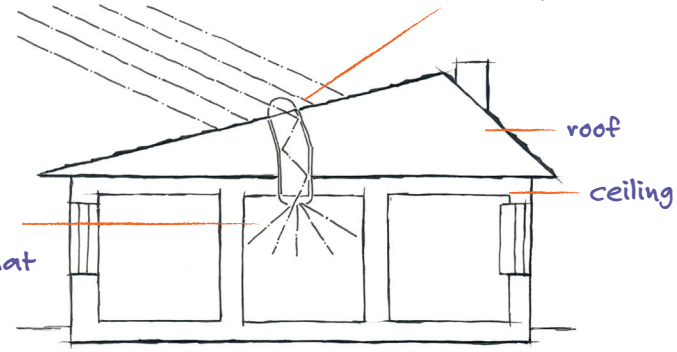
REFLECTION



The sun's rays come through the top of the pipe.

The inside of the pipe is like a mirror. The inside reflects the rays.

The sun's rays go out through the bottom of the pipe into the room so that people can see.



TESTING

	Prototype 1	Prototype 2
Describe the level of brightness you see		
(If you are measuring lumens, how many lumens?)		

PBS KIDS

MAJOR FUNDING The Lemelson Foundation ADDITIONAL FUNDING NCEES INNOVATIVE EDUCATION AWARD

Major funding is from the Lemelson Foundation. Project funding is provided by United Engineering Foundation (UEF), the National Council of Examiners for Engineering and Surveying (NCEES), and the UL Innovative Education Award.

WGBH Design Squad Global is produced by WGBH Boston.

SESSION 5: (60 MINUTES)

THE WIND POWER STATION CHALLENGE

OVERVIEW

THE WIND POWER STATION CHALLENGE! (50 minutes)

Design a machine that can use wind energy to accomplish a task, such as lifting a weight or turning a pencil to make a drawing.

SHARE SOLUTIONS WITH YOUR PARTNER CLUB (10 minutes)

Share what you have designed!

AFTER THE SESSION:

Leaders send the photos, videos, and descriptions of engineering and invention projects to your partner club.

Photo: Dan Bernstein

SESSION GOALS

ENGINEERING AND INVENTION

- Kids learn how to use the wind's force to turn a shaft and lift a weight.
- Kids learn **key science concepts**:
  - **Force** — A push or pull.
  - **Energy** — In machines, the ability to create a force.
  - **Machine** — A device that can change the amount of force.
  - **Torque** — A twisting or turning force.

ENVIRONMENTAL SUSTAINABILITY

- Kids learn how to solve community needs by using wind turbines to perform a task.
- Kids learn how wind turbines benefit the environment by replacing energy sources from fossil fuels.

GLOBAL COMPETENCE

- Kids discover an ability to act as global citizens and make a difference in the world.

PREPARE AHEAD OF TIME (about 60 minutes)

1. **Read through these instructions** and make notes.
2. **Divide up tasks** with your co-leader/assistant.
3. **Do the engineering/invention activity** yourself or together with a co-leader/assistant.
4. **Gather materials.**

For each club member:

- ☐ 1–2 sheets of scrap paper (for kids to draw designs)
- ☐ pencil

For each pair or team:

- ☐ 1–2 wooden skewers, at least 6 inches (15 centimeters) long (Substitute any straight wooden stick, if necessary.)
- ☐ 2 plastic soda bottles with plastic caps
  - 1-liter bottles are best, but 2-liter bottles also work.
  - Bottle caps from single-use water bottles (.5 liter) are usually too thin and weak to work in the activity. Use caps from 1- and 2-liter bottles.
  - Wash the caps and bottles with a solution of water and a little vinegar to disinfect them before the session.
  - Try to have extra bottles on hand in case kids want to redesign their turbines.
- ☐ scrap pieces of cardboard or other flat materials to make turbine blades
- ☐ 1–2 cardboard boxes. Try to find boxes with one short length (less than 6 inches/15 centimeters) and one taller length (greater than 10 inches/25 centimeters). Examples are a shoebox, shipping box, or shirt box.
- ☐ (optional) 2-liter plastic soda bottle as an alternate building material.
- ☐ 1–2 plastic straws
- ☐ 1 pair of scissors for 3 pairs or teams to share

For the whole club:

- ☐ your club's Recycled Materials Box
- ☐ permanent marker or crayon
- ☐ masking tape, cloth-backed tape (duct tape, for example), or packing tape
- ☐ portable electric fan or a large piece of cardboard (to create wind to test prototypes, if the day is not windy or there is no access to the outdoors)
- ☐ spool of sewing thread or string
- ☐ 1–3 small plastic bags filled with various amounts of sand or gravel to serve as weights when hooked on a paper clip. (Other options are washers, rocks, or any small heavy objects.)

- ☐ thumbtack or push pin
- ☐ paper clip
- ☐ (optional) utility knife or other sharp knife (for educator use only)
- ☐ (optional) hammer and small nail for making holes in plastic caps

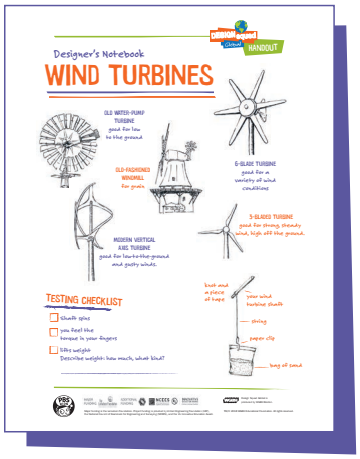
Note: If some of the materials are unavailable, feel free to use substitutes. You will be able to judge what substitutes work if you try the activity yourself before you do it with the kids.

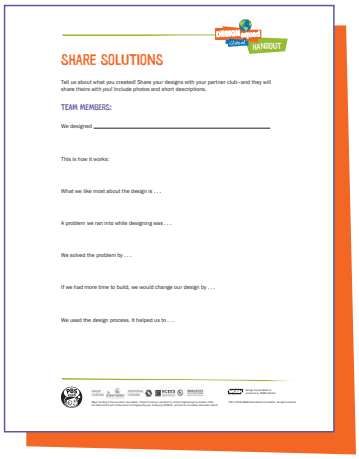
Consider a place to store the wind turbine designs after the session so that kids can add gears to them in Bonus 1: Gears on page 103.

5. **Collect items to add to the Recycled Materials Box.** After completing this session, save usable leftover materials in this box.
6. (optional) **Display the Design Board** that you created in Session 1 and use the board to save kids' sketches.
7. **Print the handouts:**

For each club member:

- ☐ **Handout:** *Designer's Notebook—Wind Turbines* on page 95
- ☐ **Handout:** *Share Solutions* on page 96





For the whole club:

- ☐ **Poster:** *The Design Process* on page 60 (if you have not already printed it for a previous session)

8. **Prepare 1–2 wind turbine shafts for each pair/team of club members.**

Kids often have the most trouble securely connecting the blades to the shaft. If you prepare a bottle cap/shaft piece for each team ahead of time, kids can focus on other tasks, such as perfecting the blades or experimenting to make the shaft do some interesting task.

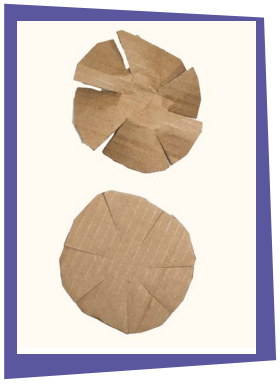
- Place the bottle cap on a flat surface with the top facing up. Push a thumbtack or push pin into the center of the cap.
- With the top of the bottle cap facing up, push the skewer all the way into the bottle cap so that it fits tightly without wiggling.
- The gear should fit tightly enough on the shaft that shaft does not turn easily.
- If the hole in the gear is too small for the skewer, use a nail to make it (a little) bigger.
- Repeat for the other cap

9. **Prepare 1 plastic bottle per team.**

- Plastic bottles are just one possibility for kids to make their prototypes. Cutting off the bottoms of the bottles may help them build faster (and more safely).
- Cut off the bottom inch (1–2 centimeters) of each soda bottle. Use scissors, a utility knife, or another sharp knife.

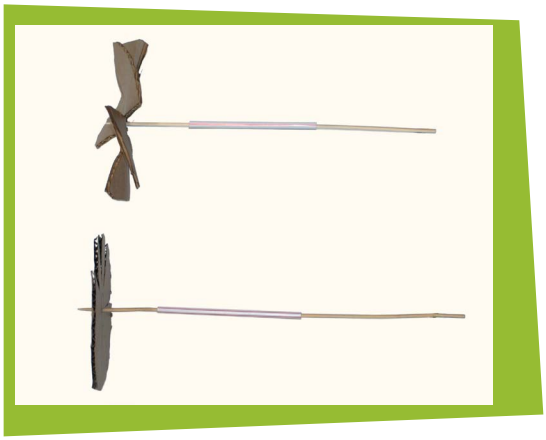
Prepare simple turbines for demonstration.

- Make cardboard turbines to help kids understand turbines and their parts. One will be for leaders' practice and the other will show kids how to position their blades.
- Cut 2 circles of cardboard around 4 inches (10 centimeters) wide.
- With a pencil, make a dot in the center of both and draw a small circle around the center about ½ inch (1 centimeter) wide.



- With scissors, make around 6–8 cuts from the edge to the circle you drew. Do this on both cardboard pieces.
- The cuts should look a little like petals on a flower. **On one cardboard circle**, twist each "petal" in the same direction, so each one stays at the same angle.

- Get 2 wooden skewers. With a thumbtack, make a small hole in the center of both cardboard circles. Press the sticks into the center so that the skewers stay in firmly.
- Get 2 straws that you can place over the skewers so that they move and turn easily. You are trying to make a handle for each stick so that it can spin easily in your hand. (If you do not have straws for this, roll a piece of paper in a tube to use as a handle.)
- One turbine should spin when you blow on it. You will use it in the "Define the Need" step. The other one is the flat one and will not spin at all. You will use it in the "Build" step to show kids an important problem to avoid. Practice the demonstrations with both turbine models.



10. **Sort through the photos** you have taken of the last 3 sessions: Flight Test, Sneakers, and Light Pipes. At the end of the session, kids will decide which photos from all the challenges they will share with their partner club.
    - Print out the best photos to show club members, or show them to kids on a computer or mobile device.
    - Remove duplicates and boring photos ahead of time. The better organized you are, the easier it will be for club members to agree on which photos to share.

LEAD THE SESSION (60 minutes)

START THE WIND POWER STATION CHALLENGE! (50 minutes)

Tell kids their challenge is to design a wind turbine that does a task, such as lifting a weight, turning a gear, or spinning a pencil to draw something—they will brainstorm many possibilities.

Show *The Design Process poster* and go over the steps with kids. Tell them they will start with the first step:

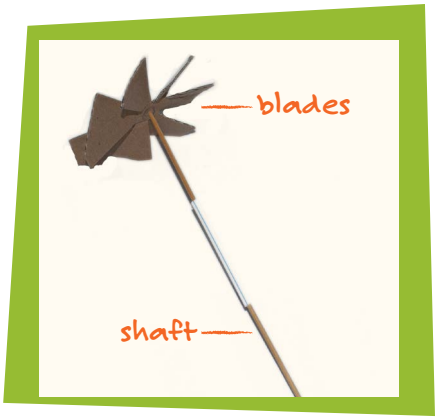
Define the Need (10 minutes)

Ask kids:

- *Have you seen a wind turbine in real life, in a book, or online? Was it big or small? (Sometimes wind turbines are also called windmills.)*
- *What do wind turbines do?*

Listen to the responses kids share. Add the following if not mentioned:

- A wind turbine gets energy from the wind and gives us the ability to do a task.
- Some wind turbines generate electrical energy. They are connected to electric generators to make electricity.
- Other wind turbines provide energy to do a physical task, such as watering farms when connected to a water pump, grinding grain for food when connected to a stone wheel, or sawing wood to build houses when connected to a saw blade.



Tell kids that the group will look at the parts of a wind turbine and how they work. Take out the cardboard turbine you made that spins when you blow on it.

Point to the **blades** on the model. Explain that the blades capture the energy from the wind.

Point to the **shaft** of the model. Explain that the shaft spins fast and sends the energy where it needs to go.

Give the model to a club member. Ask him or her to hold the model lightly by the straw (or paper tube) and blow on the blades to make them spin.

Ask the group: *When the blades spin around, what else spins?* (The shaft).

Discuss with kids:

- *A wind turbine is an amazing machine that can turn one kind of force into another.*
- *Moving air has force, it can push an object.*
- *When* (say the club member's name) *blows on the turbine, where is the force coming from and where is it going?*

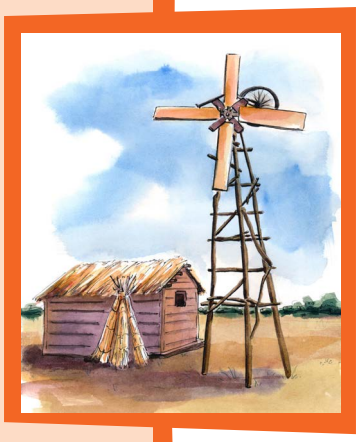
If kids seem unsure, say:

- *When* (club member's name) *blows on the turbine,* (club member's name) *is creating a force with moving air.*
- *The moving air hits the blades. (Some of the force of moving air turning the blades is called "drag"—the same force you saw in Session 2, "Flight Test.")*
- *The blades spin, creating torque. Torque is a twisting or turning force.*
- *The blades send the torque to the shaft.*
- *Many types of machines use torque from a spinning shaft. Some machines make electricity and some do physical jobs, such as moving a conveyor belt, lifting heavy boxes, or pumping water.*

Tell kids the story of a young inventor named William Kamkwamba (kam-KWAM-ba):

Photo:
Nana Kofi Acquah

William Kamkwamba: Author of the book, *The Boy Who Harnessed the Wind*



In Malawi, East Africa, a 14-year-old boy named William Kamkwamba solved a serious problem for his family. He and his 7 sisters could not get electricity unless they burned kerosene fuel in a generator. The generator created a lot of smoke and sometimes broke down.

William built a wind turbine out of an old bicycle, some trees, and pieces of plastic pipe. His mother said he was crazy, but then the turbine generated electricity so that the family could have lights in their house. Their neighbors soon started coming by to charge their phones.

William found that his first design did not provide enough electricity. He made another wind turbine with more blades, and it worked better. Next, he built a much larger wind turbine to turn a pump. It pumped water to the village's corn fields.

Visitors who came to see the wind turbine helped raise money so that William could go to school.

"It was a simple machine that changed my life," he said.

His advice for other young inventors: "Trust yourself."

Brainstorm (5 minutes)

Ask the whole group to brainstorm ideas for using a wind turbine. Begin by discussing tasks that turbines can do:

- *A turbine spins a shaft. The spinning shaft can do different tasks.*
- *With a spinning shaft, you can move objects, lift objects, turn a water pump, or turn an electric generator.*

- *What important jobs could a wind turbine do in your community?*

Ask kids some questions to get them thinking about their prototype design:

- *How could you create a small prototype of a wind turbine that could do a similar job?*
- *A prototype is a quick and simple model that lets engineers and inventors test whether their ideas will work.*
- *What is a good shape for your prototype?* If kids are unsure, say:
  - *Engineers and inventors are still experimenting with the shape of the blades and the number of blades. There are many ideas.*
  - *Think of the wind turbines you have seen, or create your own design.*
  - *Some wind turbines are small—for a home or farm, for example. Some are very large—powering an electric generator to make energy for a whole town or village.*

Design (5 minutes)

Give everyone drawing paper and pencils. Ask kids to work independently to draw their designs.

Build (20 minutes)

Tell kids that before they build, you want to show the importance of blade design. Bring out the small turbine model with the flat blades and blow on it. It should not spin. Now blow on the turbine model with the twisted blades. It should spin freely. Ask kids what they think is the difference and why the shape and position of the blades are important.

If kids are unsure, explain:

- *The blades on one turbine are at an angle.*
- *All the blades have the same angle.*
- *The moving air uses the blades' shape to push the blades around in a circle.*

Next, show kids how you twist each cardboard blade on the flat model so that it spins too. Tell them they can create angles on their blades by twisting or designing the blades that way.

Give club members the handout: *Designer's Notebook—Wind Turbines*. Ask kids to work in pairs or teams. Tell them they will each contribute their design ideas to make a prototype.

Show kids the materials for the activity, including the **bottle caps with skewers** and **plastic bottles with the bottoms cut off** that you prepared earlier. Show kids the materials in the **Recycled Materials Box**. Ask questions to get them thinking about how to work with the materials:

- *Do you remember the parts of the small turbine we looked at?* (The blades and the shaft.)
- *What kinds of materials could work as blades?*
- *Look at your handout. Wind turbines also have a tower that supports the blades and the shaft.*
- *What could you use to create a tower to hold your wind turbine up?*

Ask teams to **start building** their designs. The work may seem challenging at first and kids may feel they need a lot of help. Let them explore options on their own. As you watch them working, ask **questions** to help them reach their own solutions, such as:

- *How could you keep the blades securely connected to the shaft?*
- *What could you do to make the tower hold the shaft but let the shaft turn easily?*

Remind kids of the advice of William Kamkwamba: "Trust yourself!"

Test and Evaluate (10 minutes)

Ask the teams to try two tests and evaluate their designs. To test their prototypes, create wind with the fan or wave a large piece of cardboard up and down.

Test 1: Do your turbine blades spin?

If the shaft does not spin, help kids using the Problem-Solving Tips below.

If the shaft spins, tell kids to gently pinch the spinning shaft between their fingers.
Tell them:

- *When you pinch the spinning shaft with your fingers, you are feeling its torque.*
- *Experiment with your design to see what changes in the design provide more torque.*

Problem-Solving Tips

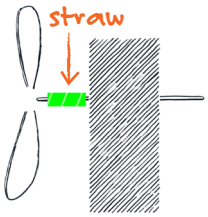
WHAT IF

the shaft does not spin in the wind?

- **Ask:** *Are all your blades at an angle? Are all the angles in the same direction?*
- If the team is using plastic for the blades, tell them to twist the material with their hands to make the blades bend at the same angle.

the wind turbine does not spin freely?

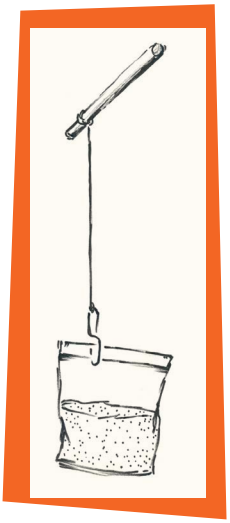
- **Ask:** *Is the shaft pressing against something? What could you do to make the shaft turn more smoothly?* (If the shaft is held in one or more holes in the tower material, tell teams they could wiggle the shaft to make the hole wider or place a piece of plastic straw inside the hole.)
- **Ask:** *Is a blade hitting the tower? What could you do to fix it?* (One idea: cut a piece of straw, about ½ inch (1–2 centimeters), and place it between the blades and the tower, as shown below.)



the prototype falls over when you test it?

- *Connect the tower to a secure base (such as a large cardboard box) or tape the whole thing to a table.*

Test 2: Lift a weight: How much torque (twisting or turning force) does your turbine produce?



Tell kids:

- *Tie a piece of thread to the shaft. Use a small piece of tape (the size of a fingernail) to secure the knot.*
- *Bend a paper clip into a hook shape. Attach the other end of the thread to the paper clip.*
- *Attach a small bag of sand to the paper clip.*
- *See if the shaft can lift the weight using the wind created by the fan or by waving a large piece of cardboard up and down.*
- *If your turbine can lift a heavy weight, it has a lot of torque!*

Remember to **take photos** to share with your partner club!

Redesign

Ask: *What can you do to increase the force?*

If kids are unsure, suggest the following:

- *Change the number of blades.*
- *Make the blades a different shape or size.*
- *Change the angle of the blades.*
- *Make the shaft turn more easily in the tower.*

Fail Fast, Succeed Sooner!
Remind the group that the design process is all about **learning from problems and trying again.** Ask kids to redesign their turbines so that the blades and shaft turn.

If there is time: tell teams their wind turbines can also be drawing machines—if teams **attach a pencil to the shaft,** the pencil will draw circles. They can experiment to create other shapes and patterns.

SHARE SOLUTIONS WITH YOUR PARTNER CLUB (10 minutes)

Tell kids they will show their designs and prototypes with their partner club! Their partner club has done the same engineering and invention challenges and will also share what they have built.

Point to the last step on *The Design Process* poster: Share Solutions. Ask kids:

- *Why is sharing solutions a good idea for engineers and inventors?*

Add any of the following that the kids do not say:

- *so they can hear about new ideas, interesting ways to use materials, or communities that need a similar invention*
- *so they can get advice that would help them solve a problem they are having with their invention*

Show kids a selection of the photos you took of the 4 engineering and invention challenges they completed before today's session: Flight Test, Sneakers, Light Pipes, and Wind Power Station. Include some drawings from the Design Board, if you are able.

- Ask kids which designs they would like to present to their partners. They may decide to present 1 or all 3.
- Ask pairs/teams to fill out a *Share Solutions* form for each challenge together, choose photos, and pick drawings from the Design Board to illustrate their designs.
- If there is time (and your partner club leader has the necessary technical capabilities), take a video of kids as they describe 1 or more of their designs. Try to give every club member a chance to speak, or at least to appear in the videos.

Tip: Include a short description with every photo. Descriptions will make it clear to your partner club what you want them to notice in the photos.

Ask kids to clean up.

- **Ask teams to store the wind turbines, if possible.** They can use the turbines again in Bonus 1: Gears. Otherwise, let them take them home or ask them to take them apart and place the pieces in the Recycled Materials Box.
- **Resupply your Recycled Materials Box** with the usable leftover paper and materials from the session.
- **Give each kid a sticker for their membership card. Collect the cards** or ask kids to store them.

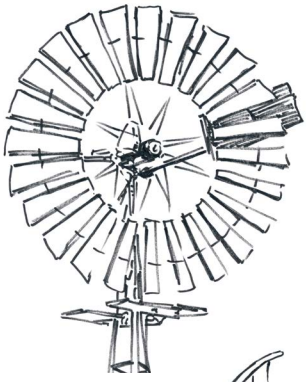
AFTER THE SESSION: SHARE SOLUTIONS (SEND)

- Attach the photos and short descriptions to the completed *Share Solutions* forms, and scan and send them to your partner club leader.
- Send videos if you took them.
- Feel free to experiment with other ways to share club members' solutions. You could make a PowerPoint presentation of kids' designs, for example.
- Whatever you choose, make sure your partner club leader has the technology to be able to share kids' solutions with his or her club members.

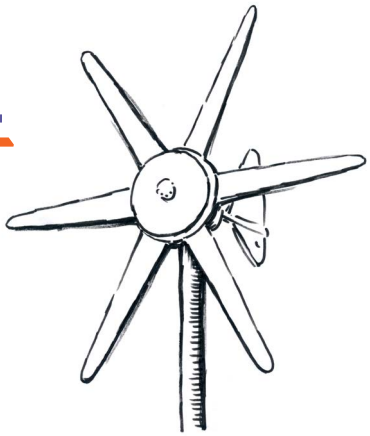
DESIGN squad Global HANDOUT

Designer's Notebook

WIND TURBINES

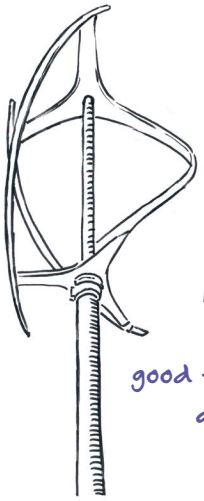


OLD WATER-PUMP TURBINE
good for low to the ground



6-BLADE TURBINE
good for a variety of wind conditions

OLD-FASHIONED WINDMILL
for grain

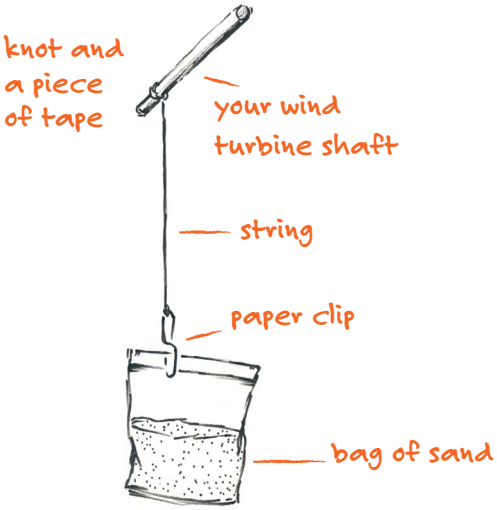


MODERN VERTICAL AXIS TURBINE
good for low-to-the-ground and gusty winds.

3-BLADED TURBINE
good for strong, steady wind, high off the ground.

TESTING CHECKLIST

- ☐ Shaft spins
- ☐ you feel the torque in your fingers
- ☐ lifts weight
  Describe weight: how much, what kind?



PBS KIDS

MAJOR FUNDING The Lemelson Foundation ADDITIONAL FUNDING NCEES INNOVATIVE EDUCATION AWARD

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WGBH Design Squad Global is produced by WGBH Boston.

DESIGN squad Global HANDOUT

SHARE SOLUTIONS

Tell us about what you created! Share your designs with your partner club—and they will share theirs with you! Include photos and short descriptions.

TEAM MEMBERS:

We designed _____

This is how it works:

What we like most about the design is . . .

A problem we ran into while designing was . . .

We solved the problem by . . .

If we had more time to build, we would change our design by . . .

We used the design process. It helped us to . . .

PBS KIDS

MAJOR FUNDING The Lemelson Foundation improving lives through invention

ADDITIONAL FUNDING NCEES advancing licensure for engineers and surveyors INNOVATIVE EDUCATION AWARD POWERING A SUSTAINABLE TOMORROW

Major funding is from the Lemelson Foundation. Project funding is provided by United Engineering Foundation (UEF), the National Council of Examiners for Engineering and Surveying (NCEES), and the UL Innovative Education Award.

WGBH Design Squad Global is produced by WGBH Boston.

SESSION 6:

PARTNER EXCHANGE PARTY

(60 MINUTES)

OVERVIEW

SHARE SOLUTIONS (30 minutes)

See videos, photos, and descriptions of your partner club's engineering and invention projects.

CELEBRATE (30 minutes)

Enjoy treats and receive your Design Squad Global *Certificate of Achievement.*

SESSION GOALS

ENGINEERING AND INVENTION

- Kids see engineering and invention as careers that are creative and make a difference in the world.
- Kids are reminded that they have the skills and abilities of engineers and inventors: persistence, creativity, communication, and teamwork.

ENVIRONMENTAL SUSTAINABILITY

- Kids think creatively about sustainable design by considering alternative materials.
- Kids brainstorm inventions that do not need to be powered by fossil fuels.

GLOBAL COMPETENCE

- Kids communicate and collaborate with peers from a different part of the world.
- Kids acquire an openness to new ideas, different ways of thinking, and unfamiliar situations.

ASSESSMENT (OPTIONAL)

Record kids' answers to questions about engineering/invention and their experiences with their partner club. Then, compare the answers with the ones you recorded in the first session. The assessment will tell you how much your club members have grown.

PREPARE AHEAD OF TIME (60–120 minutes)

1. **Read through these instructions** and make notes.
2. **Divide up tasks** with your co-leader/assistant.
3. **Gather materials.**
   - ☐ snacks and drinks
   - ☐ copies of the *Share Solutions* forms your partner club sent.
   - ☐ photos, descriptions, and videos of your partner club's projects, downloaded (Check ahead of time that all the videos can be played.)
   - ☐ computer with internet connection to show kids the Design Squad Global website
   - ☐ (optional) the *Assessment* form you filled out in Session 1. You will use it to record kids' answers to 3 questions in this session. (The questions are also listed in the *Assessment* form handout on page 48.) By comparing their answers from the beginning and end of the club, you can evaluate kids' growth and understanding.

Print out handouts:

- ☐ **Handout:** *Certificate of Achievement* on page 102. Print in color, if possible, and fill one out for each club member. Think about something you can announce about member when you award the certificates: great teamwork, creativity, persistence, etc.
- ☐ **Poster:** *The Design Process*, on page 60. Give each kid a copy to keep.

4. **Consider** possible extension activities.

   Think about ways you might extend the club through a live video chat with your partner club or by creating an exhibit.

   - **Live Video Chat:** If possible, schedule a live video chat with your partner club. If there is a time difference between the 2 clubs, Saturday or Sunday may be the best days. Talk to your partner club leader before the live video chat, about questions that kids will ask each other.

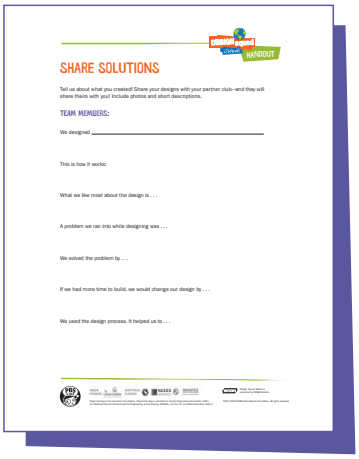
- **Global Invention Exhibit:** Create an exhibit featuring your club's engineering solutions and your partner club's photos and sketches. Invite "the public" (parents, friends, community members, etc.) to view the clubs' work.
- **Bonus Activities:** If you have more time, there are 2 bonus activities at the end of the guide. Each activity is 1 hour.

LEAD THE SESSION (60 minutes)

SHARE SOLUTIONS (30 minutes)

Tell kids:

- *You are now going to do the last step of the design process: share solutions!*
- *By sharing designs, partner clubs learn from each other.*
- *Your partner club's designs could inspire you to invent more things, and your designs could inspire them.*


SHARE SOLUTIONS

HANDOUT

Tell us about what you created! Share your designs with your partner club–and they will share theirs with you! Include photos and short descriptions.

TEAM MEMBERS:

We designed _____

This is how it works:

What we like most about the design is . . .

A problem we ran into while designing was . . .

We solved the problem by . . .

If we had more time to build, we would change our design by . . .

We used the design process. It helped us to . . .

Show kids the *Share Solutions* forms and any video presentations your partner club sent. Ask for comments after each one.

Ask kids:

- *Now that you have done some engineering and inventing yourself, how would you describe what they are? Complete these sentences: "I used to think engineering and invention were... Now I think they are..."*
- *Could you see yourself becoming an engineer or inventor in the future? If so, what kinds of problems would you like to work on?*
- *We talked about some professional engineers during the club sessions. What is interesting about the work they do? How do their inventions help people? How did they use their creativity to solve problems?*
  - *Anthony Oyatayo, the engineer who improved rollercoasters*
  - *The inventors who created the bottle lights for homes*
  - *The engineers who built the Village Drill for digging wells*
  - *William Kamkwamba, who made a wind turbine for his village (He has grown up and gone to college, and now has a degree in engineering!)*
- *Now that you have learned more about the kids in your partner club, what has surprised you about them? Complete these sentence: "I used to think... about my partner club. Now I think..."*

Discuss with kids the impact of inventors on the environment. Ask: *How does the way you design and use things in our community affect people in other places?*

If kids are unsure, suggest and ask:

- *Products are manufactured across the world. A design you create may cause environmental problems where it is made. Engineers and inventors have to think about sustainability from a global perspective.*
- *Think about the life cycle of your designs. What happens when they are no longer useful? Are they thrown away or reused?*
- *Inventing is about understanding the needs of communities other than your own. How could your experience with your partner club help you as an inventor solve new problems and help others?*

DISCUSS YOUR CLUB'S BRAINSTORM BOARD (5 minutes)

Talk about the designs kids added to the brainstorm board in Session 1 and during the challenges in the other sessions. If possible, look at some prototypes that teams made in the challenges. **Ask and discuss:**

- *You have created some designs that work toward solving big problems in the world and problems you see in your neighborhood. In Session 1, we brainstormed ways to solve problems such as lack of food, unclean water, and pollution in the ocean and on land. Do you have any of these problems in your neighborhood?*
- *Pick one of your team's prototypes that you would like to change or improve. What would you change about the design?*
- *Are there designs on the board you would like to make a prototype of?*
- *If your team had one more club session to work on a project, which project would you pick? What more would you do with the project? Would you change anything about your design?*

CELEBRATE! (25 minutes)

- **Share some treats!** It is time to celebrate!
- **Present a *Certificate of Achievement* to each kid.** Ask each club member to get his or her certificate. Say something about each club member—for instance, their successes, examples of their perseverance when challenged, their creativity to solve a problem, or times they worked well in a team.
- **Give each kid a sticker** for their membership card!
- **Encourage kids to continue designing and inventing!** Give each kid a copy of *The Design Process* poster. Tell kids that they now have the skills and experience to invent things on their own!
- **Share the *Design Squad Global* website.** Another way to inspire kids to continue inventing is through the videos and ideas on the Design Squad Global website: **pbskids.org/designsquad**. Kids will find more activities on the website like the DSG club challenges and inspiration for future inventions.

DESIGN squad Global

CERTIFICATE OF ACHIEVEMENT

CONGRATULATIONS

for doing a world-class job
as an engineer and inventor
for environmental sustainability
in the Design Squad Global Club!

THANK YOU FOR SHARING YOUR DESIGNS WITH US.

NOW GO OUT AND SHARE THEM WITH THE WORLD!

Signed,

Club Leader

MAJOR FUNDING The Lemelson Foundation
ADDITIONAL FUNDING NCEES advancing licensure for engineers and surveyors INNOVATIVE EDUCATION AWARD

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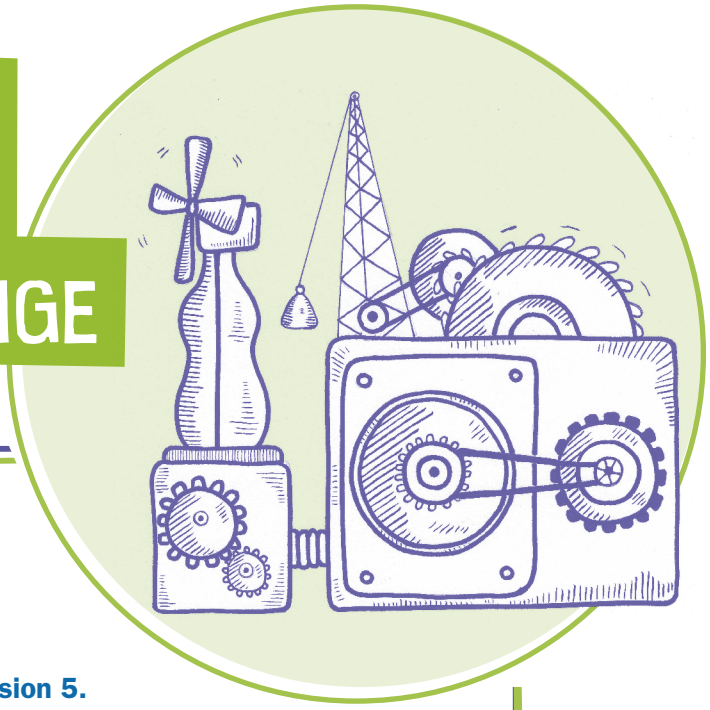
BONUS ACTIVITY 1: THE GEARS CHALLENGE

(60 MINUTES)



OVERVIEW

THE GEAR CHALLENGE! (60 minutes)

Add gears to your wind turbine from Session 5. Make the turbine into a machine that increases force to lift a heavier object.

SESSION GOALS

ENGINEERING AND INVENTION

- Kids investigate gears and combine them to generate more torque.
- Kids learn key **science concepts**:

  Gears — Wheels that have teeth. Gears change the force or torque of a machine.

  Force — A push or pull.

  Torque — A twisting or turning force.

  Machine — A device that can change the amount of force or change its direction.

ENVIRONMENTAL SUSTAINABILITY

- Kids learn to use the energy from wind to perform a task.
- Kids discuss ways to replace machines powered by fossil fuels to benefit the environment.

GLOBAL COMPETENCE

- Kids learn how communities use mechanical systems to solve local problems.

PREPARE AHEAD OF TIME (about 60 minutes)

1. **Read through these instructions** and make notes.
2. **Divide up the tasks** with your co-leader/assistant.
3. **Do the engineering/invention activity yourself** or together with your co-leader/assistant.
4. **Decide which activity** your club will do:
   - ☐ **Option 1: Gears.** The full Gears activity works best for clubs with members who have completed the other sessions and are 10–13 years old. Kids connect gears to their wind turbines to change and direct the torque of their wind turbines.
   - ☐ **Option 2: Block and Tackle.** The Block and Tackle challenge on page 114 is easier than the Gears activity and also requires fewer materials. The projects is a simpler way to design a machine for the wind turbines.
5. **Gather materials**.

For each club member:

- ☐ 1–2 sheets of scrap paper (to draw designs)
- ☐ pencil

For the whole club:

- ☐ Recycled Materials Box
- ☐ spool of sewing thread or string
- ☐ masking tape, cloth-backed tape (such as duct tape), or packing tape
- ☐ permanent marker or crayon
- ☐ nail and hammer for making holes in plastic caps
- ☐ 3–4 small plastic bags (reused, if possible) filled with various amounts of sand or gravel to create a range of weights, from about 1/4 to 2 pounds (.1 to 1 kilograms). (Scoop or spoon sand or gravel into bags. Instead of sand/gravel, you could use metal washers or bolts.)
- ☐ 3–4 paper clips (any size)
- ☐ portable electric fan or a large piece of cardboard (to create wind to test prototypes, if the day is not windy or there is no access to the outdoors.)
- ☐ (optional) a brick or heavy rock, to be used as a weight

Option 1: Gears

For the demonstration:

- ☐ 2 plastic soda bottle caps to be used as gears
  - Use caps from 1-liter and 2-liter bottles, or similar-sized caps from larger or smaller bottles. Most bottle caps from single-use water bottles (.5-liter) are too thin and weak to work.

- Wash the caps with a solution of water and a little white vinegar to disinfect them.

☐ 1–2 plastic container lids (larger than the bottle caps) to be used as gears (For example, the lids from plastic peanut butter jars and other food containers.)

☐ scrap cardboard for making gear teeth

- Large, sturdy boxes often have the thickest cardboard, which will make the best gear teeth.
- The cardboard for a team's machine should come from the same box. (That way, all the gears will have teeth that match.)

☐ 2 wooden skewers, at least 6 inches (15 centimeters) long (Substitute any straight wooden stick, if necessary.)

☐ scissors

☐ thumbtack or pushpin

For each pair or team:

☐ team members' wind turbines from Session 5: Wind Power Station

☐ 4–5 plastic soda bottle caps to be used as gears

- Use caps from 1-liter and 2-liter bottles, or similar -sized caps from larger or smaller bottles. Most bottle caps from single-use water bottles (.5 liter) are too thin and weak to work.
- Wash the caps with a solution of water and a little white vinegar to disinfect them.

☐ 1–2 plastic container lids (larger than the bottle caps) to be used as gears (For example, the lids from plastic peanut butter jars and other food containers.)

☐ scrap cardboard for making gear teeth

- Large, sturdy boxes often have the thickest cardboard, which will make the best gear teeth.
- The cardboard for a team's machine should come from the same box. (That way, all the gears will have teeth that match.)

☐ 5–7 wooden skewers, at least 6 inches (15 centimeters) long (Substitute any straight wooden stick, if necessary.)

☐ thumbtack or pushpin

☐ 1–2 pairs of scissors

☐ hot glue gun and glue sticks for the whole club (Note: If you do not have access to hot glue, substitute rubber cement adhesive. Both types of glue dry fast enough to allow kids to test within a session. If you do not have access to either adhesive, consider the Option 2 activity, Block and Tackle.)

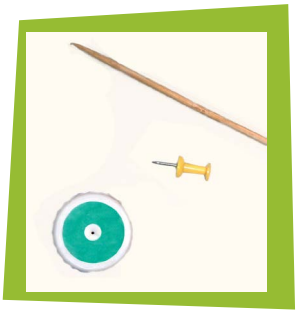
Option 2: Block and Tackle

For each pair or team:

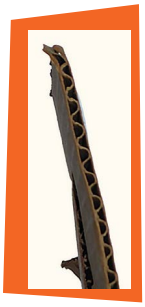
☐ team members' wind turbines from Session 5: Wind Power Station

- ☐ large paper clip
- ☐ 3 wooden skewers, at least 6 inches (15 centimeters) long (Substitute any straight wooden stick, if necessary.)
- ☐ thumbtack or pushpin

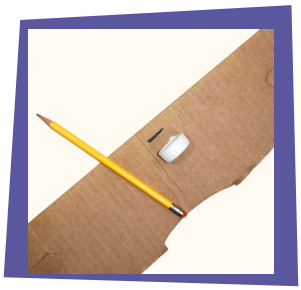
6. **Make 2 models of gears** to show kids during the activity.



- Place the bottle cap on a flat surface with the top facing up. Push a thumbtack or pushpin into the center of the cap.
- Push the skewer through the top of the bottle cap so that it fits tightly without wiggling and easily turns the cap. If the hole is too small, use the hammer and nail to make it just a *little* bigger.

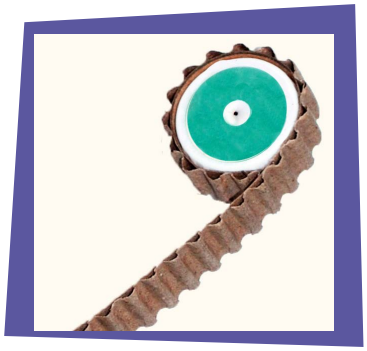


- Next, make cardboard teeth for the gear. Find the corrugated edges of the cardboard. The corrugated edges show the wavy pattern of the inner layer. (Corrugation gives the cardboard strength!) Mark the height of the bottle cap near the edge of one of the corrugated edges of the cardboard.

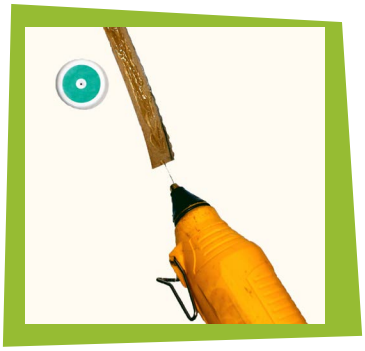


- Use a ruler to draw a straight line near the edge of the cardboard through the mark. Cut along the line. This will make a strip of cardboard that is the height of the bottle cap.

- Carefully pull off the paper layer on one side of the cardboard strip to show the corrugations underneath. The bumps will become your gear teeth.
- Wrap the cardboard strip around the bottle cap. Cut the ends so that the ends meet. The strip should not overlap. On each end, leave one full cardboard tooth.



- Apply glue to the smooth side of the cardboard strip. Gently press the side of the cardboard strip with the glue around the bottle cap. Be careful not to damage the cardboard teeth.
- Make a second model with a larger cap to show kids how the gears work together.
- You will show kids the gears in the Define the Need section. You will show kids how to build gears at the start of the Build section.



One way to **remove the paper layer** on one side is to bend the cardboard strip into a half circle. The layer of the cardboard on the outside of the circle will then become easier to remove.

6. **Print the handouts.**

For the whole club:

☐ **Poster:** *The Design Process* on page 60 (if you have not already printed it for the previous session)

LEAD THE SESSION (60 minutes)

START THE GEAR CHALLENGE!

Tell club members: *Your challenge is to add gears to your wind turbine to make it into a machine that can lift a heavy object.*

Show *The Design Process* poster and go over the steps with kids. Tell them they will start with the first step:

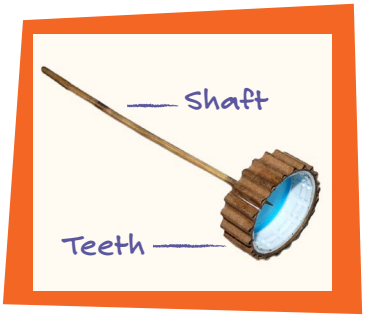
Define the Need (10 minutes)

Ask: *What do gears do?*

Listen to the ideas that kids share. Add the following, if not mentioned:

- Gears work inside machines.
- They are shaped like wheels with little bumps called teeth.
- The teeth help them turn other gears.
- Gears change the force of a machine.
- Gears can provide a machine with more force to make it easier to do a task. For example, a bicycle with many gears is easier to pedal up a steep hill than a bicycle with only one gear. A rider can provide the same force on the pedals during the whole trip, but the rider can change gears to provide more force to the wheels to make it easier to climb a hill. On flat roads, the rider can change gears to go faster and cover more distance.

Give kids the bottle cap gears you made for the demonstration, and show how they work together. Let kids handle them. **Ask and discuss:**



- *What do the bumps on the gears do?* (Point to the cardboard teeth.)
  - The bumps are called **teeth**.
  - The teeth of one gear fit together with the teeth of another gear. The teeth help the gears move together.
- *What do the other parts do?* (Point to the shaft and show kids how the shaft turns the gear on your model.)
  - The **shaft** connects the gear to other parts. The shaft can connect to the wind turbine. The shaft can also connect to a string or rope to lift a weight. The shaft could even connect to a small drill bit to drill a hole.

Explain to kids:

- Every moving object—such as a bicycle—has force. Force is a push or pull.
- When you design gears, you have the amazing ability to create more force or less force.
- For example, gears could help you lift something very heavy. You could lift a recycling truck—weighing about 33,000 pounds (15,000 kilograms)—in the air to fix it!
- Gears also have the force dig a well deep into the ground for fresh water. Next, we will read about an incredible human-powered, well-digging machine.

Read the story "One Big Gear, One Deep Well" below and show kids the picture:

One Big Gear, One Deep Well

A team of inventors in Utah, USA, call their machine the Village Drill. People use the machine to drill wells so that communities around the world can have clean water. The drill is a big yellow gear that 8 people use together. People circle around the gear and hold onto handles, turning the gear together.

The gear increases the human muscle force to turn a drill bit. The drill bit (a long shaft that looks like a big screw) goes into the ground down through the hard soil. It can go as deep as 270 feet (82 m). That is about the length of the tallest tree, or two times the length of most airplanes.

The Village Drill is used in countries such as the Philippines, Madagascar, Kenya, Malawi, Mexico, and the US.

Explain to kids:

- *Around the world, people need new machines that help drill wells, build houses, lift heavy rocks to clear land, transport us in vehicles, and do other tasks.*
- *With newly invented machines, people can use the energy of wind, water, or our own muscles to do tasks that were once done with electricity or fossil fuel.*

Brainstorm (5 minutes)

Ask kids to brainstorm ideas for an invention that uses their wind turbines to accomplish an important task. **Allow kids to brainstorm and design large, complicated machines** in this and the following section. Kids will build a simple prototype to test their gear size and designs in the Build section.

Begin by asking kids some questions about engineering projects with gears:

- *What jobs could a machine capable of great force do in your community?* (Lift heavy objects, such as big crates of fruit, stacks of wood, bales of hay, ships' cargo, and boulders. Cut holes in the side of a mountain to get rock to build with. Move products efficiently down a conveyor belt to improve the production of needed goods.)

- *How could you create a small prototype of a machine that could do a job?* (A prototype is a quickly-made, simple model that lets an engineer or inventor test if their idea will work.)
- *What kind of gears should you choose for your machine?*

Tell kids:

- *A small gear connected to a large gear gives a machine more force.*
- *A large gear connected to a small gear gives a machine more speed.*

Design (5 minutes)

Give kids drawing paper and pencils. Ask kids to work independently to design a machine that would be useful to the community.

Build (5 minutes)

Tell kids to work in pairs or teams. They will add gears to one of their wind turbines. Tell them:

- *Decide which wind turbine you will use.*
- *To the wind turbine, you will be adding a prototype of the machine you sketched in your designs.*
- *Choose a design from the members of your group or combine the best ideas into one design.*
- *You will start by making a simple version of the machine. The machine will provide more force than the wind turbine alone.*
- *Later, you will test the force by lifting objects of various weights. You will start with lighter objects and switch to heavier and heavier objects until the machine will not lift any more weight.*

Give kids instructions on safely using the hot glue gun:

- Place the hot glue gun on a table away from people when not using it.
- After applying hot glue to a strip of cardboard, press and hold the strip on the bottle cap until they are secured to each other.
- Avoid getting the hot glue on your hands. It will burn your skin!
- Wait 30 seconds or more for the glue to cool before touching the glue.

Show kids the materials for the activity.

Demonstrate making a gear to the group while describing the steps on page 106.

Ask teams to make their own gears.

Ask kids to connect the gears to the turbine.

Ask kids to connect the gears to their wind turbines. **Tell them:**

- *Very gently remove the shaft from the gear. Be careful not to damage the teeth.* (The gear must be out of the shaft for the shaft to go through the wind turbine tower.)
- *You should already have a shaft on your wind turbine prototype from Session 5. If you do not, create a shaft to connect the wind turbine to the gear.*

- *Attach the gear to the wind turbine shaft on the other side of the tower. (You may have to wiggle the gear to get the shaft to connect, or make the hole on the gear slightly bigger.)*
- *The flat side of the bottle cap should face your tower. This position makes the gear spin more easily against the plastic or cardboard tower.*
- *The shaft has to fit tightly in the bottle cap hole. (It should not turn inside the bottle cap hole). See the Problem-Solving Tips for the use of hot glue to secure the shaft. Also, the shaft must be able to turn easily in the tower.*
- *The gear and blade should now be on the same shaft. Test that the gear spins with the wind turbine blades.*

Tell kids to add a second gear to the machine. **Tell kids:**

- *The energy source in your prototype comes from the turbine blades. A gear connected to an energy source is called a "drive gear."*
- *The teeth of the drive gear have to connect well for it to turn a second gear.*
- *A small drive gear connected to a larger gear will give the larger gear's shaft more force.*
- *A large drive gear connected to a smaller gear will make the smaller gear's shaft turn faster.*
- *Experiment with different sizes for the second gear, to create more force or to make the shaft turn faster.*

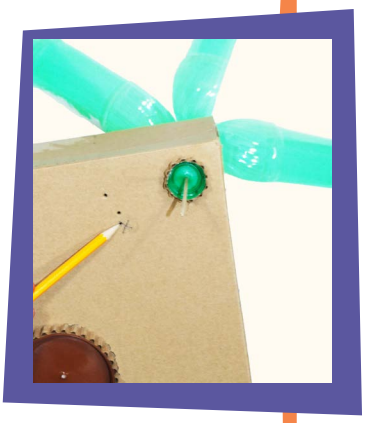
Fail Fast, Succeed Sooner!

Remind the group that the design process is all about **learning from failure** and trying again. If kids' machines are not working, tell them to redesign their gears. Check that the teeth connect as the gears turn.

Remember to **take photos** to share with your partner club!

Problem-Solving Tips

How can I make the gears spin together?



- The gear teeth need to connect for the gears to turn together.
- When adding another gear to the tower, align the gears' teeth so that they connect. Mark the location where the shaft of the second gear's would go with a pencil or small puncture. Make a hole for the shaft on the mark.
- connect the second gear to its shaft.
- test that the teeth of the 2 gears connect.
- If your second gear is too close to or too far from your first gear, remove the second gear and mark a new spot for its shaft, make a new hole, and try again.

What if the shaft slips out of the gear?

- Add hot glue inside the bottle cap around the hole where the shaft enters. Insert the shaft and hold it in place until the glue hardens.
- Start again with another bottle cap and make a smaller hole for the shaft.

What if one of the shafts keeps bending?

- Add a support structure (as shown below, right) that holds up the shaft after it leaves the wind turbine. One option is to add a cardboard structure that stands apart from the wind turbine. The support structure can support the end of the shaft.

How can I make my gears provide more force?

- Add more gears!
- Reduce friction (the rubbing of parts against each other). Make the parts move more easily by making the holes in your tower bigger or adding a plastic straw between the structure and the shaft.
- Check if the heavy object in the test is rubbing against parts of the machine when it is raised. Stop the object from touching the machine, or at least reduce the friction of the object against the machine.
- Redesign the wind turbine's blades to get more force from the wind.
- **Hint for more advanced club members:** A machine with 3 or more gears can provide even more force. But kids will need to learn how to make "compound gears"—2 gears of different sizes moving together on the same shaft.

Test and Evaluate (5 minutes)

Tell club members about twisting forces:

- *Sometimes a force moves in a straight line. Examples of a force moving in a straight line are the force of drag on an airplane or the force of the ground on your sneakers.*
- *Sometimes a force twists or turns.*
- *A twisting or turning force is called torque.*
- *The force from your wind turbine shaft is torque.*

Ask the teams to test the torque of their machines and evaluate their designs. To test wind turbine prototypes, create wind with the fan or by waving a large piece of cardboard up and down. Give kids the plastic bags with different amounts of sand or gravel in them. The bags should weigh various amounts, from light to heavy.

Describe the test: *Try to lift a bag of sand with your machine. How much torque does your turbine produce?*

- *Tie a piece of thread to the shaft. Use a small piece of tape to secure the knot.*
- *Bend a paper clip into a hook shape. Attach the other end of the thread to the paper clip.*
- *Attach a small bag of sand to the paper clip.*
- *See if the shaft can lift the bag using only the wind.*
- *If your machine can lift the heaviest bag of sand, it produces a lot of torque. Congratulations!*
- *Try increasingly heavier bags to see the maximum amount of sand your machine can lift.*

Redesign (15 minutes)

Ask kids to redesign their gears to be sturdier or provide more force.

Ask kids to clean up:

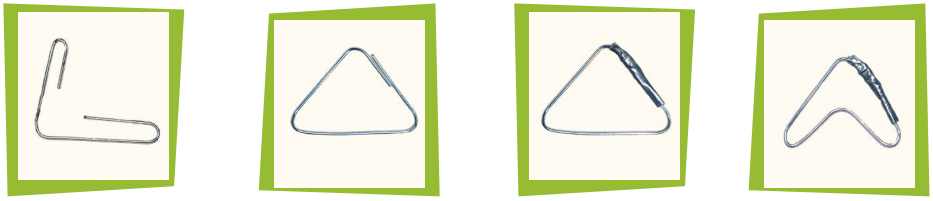
- **Let kids keep their prototypes,** if possible, and remind them to bring the prototypes back for the party in Session 6. (If the club's space has storage, ask kids to keep prototypes on site for the last session.)
- **Ask kids if you can hold their brainstorm and design sketches** for the partner exchange.
- **Resupply your Recycled Materials Box** with the usable leftover paper and materials from the session.
- **Give each kid a sticker** for their membership card. **Collect the cards** or ask kids to store them.

OPTION 2: BLOCK AND TACKLE

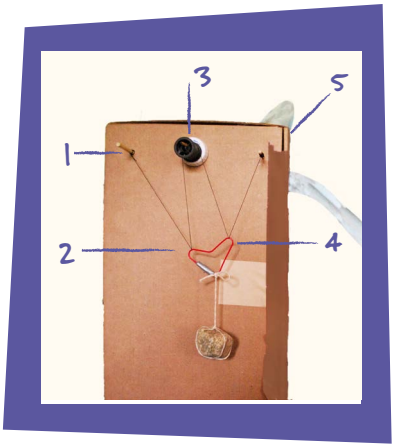
If you do not have a hot glue gun and sticks, or rubber cement adhesive, show kids how to make a related machine called a "block and tackle." These ancient machines are at least 5,000 years old. They are still used in the design of modern cranes to build buildings and by aerospace companies to lift aircraft and rockets.

A block and tackle operates much like gears to increase force. The machine, shown below, doubles the force on the object (the stone), making it easier to lift.

- To start, bend a large paper clip into a heart shape and tape the ends together. This will function like a pulley.



- Place an object in the center of your machine that turns easily, such as an empty thread spool or piece of a plastic straw, to serve as a wheel.
- Add a piece of thread:
    1. Tie one end of the thread to a fixed object on the tower to anchor it,
    2. Put the thread through one side of the paper clip/pulley,
    3. Loop the thread up over the freely spinning object,
    4. Put the thread through the other side of paper clip/pulley, and
    5. Tie the thread to your wind turbine shaft. (Add a piece of tape to secure it.)
- To Test and Evaluate, use the same steps as shown on the previous page.



EXTENSION: THE BRICK CHALLENGE!

If you have more time in the session—between 90 minutes and 2 hours—try The Brick Challenge!

Tell kids: *Test if your machine can lift one half of a brick* (or a rock of equal weight). *Then, try to redesign the machine to lift a whole brick* (or bigger rock)!

BONUS ACTIVITY 2: THE TABLEWARE-TO-GO CHALLENGE

(60 MINUTES)

OVERVIEW

THE TABLEWARE-TO-GO CHALLENGE

(60 minutes)

Invent a device, carrier, or system to carry reusable spoons, forks, knives, and chopsticks.

SESSION GOALS

ENGINEERING AND INVENTION

- Kids explore the design process further by learning the importance of redesigning.
- Kids consider new materials for making tableware.
- Kids learn **key science concepts**:

  Single-use — An object meant to be used once, then thrown away.

  Reusable — A material that can be used over and over again.

  Biodegradable — A material that breaks into small pieces that do not harm the environment after the material is thrown away.

  Compostable — A material that breaks down quickly (within a few months) and makes soil healthier.

ENVIRONMENTAL SUSTAINABILITY

- Kids think about the benefits and problems of various materials.
- Kids evaluate materials according to their life cycles.

GLOBAL COMPETENCE

- Kids become more aware of how the choice of materials in designing solutions affects people around the world.
- Kids discover their own agency—their ability to act as global citizens and make a difference in the world.

PREPARE AHEAD OF TIME (about 60 minutes)

1. **Read through these instructions** and make notes.
2. **Divide up the tasks** with your co-leader/assistant.
3. **Plan to take photos/videos**, or ask your co-leader or assistant to do this task. (You will share these photos and videos with your partner club in Session 5.)
4. **Do the activity** yourself or with your co-leader/assistant.
5. **Gather materials.**

For each club member:

- ☐ pencil
- ☐ 1–2 sheets of scrap paper to draw designs

For the whole club:

- ☐ The main source of materials for this activity will be your club's Recycled Materials Box, described on page 36. After completing the session, save usable leftover materials in this box.
- ☐ plastic water bottle for the demonstration
- ☐ 3–5 pairs of scissors
- ☐ thick cloth-backed tape, such as duct tape (Packing tape will also work.)
- ☐ (optional) examples of single-use, plastic spoons, forks, and knives, or wooden chopsticks (Before using, these should be washed with soap.)

6. **Print the poster:** *The Design Process* on page 60.

LEAD THE SESSION (60 minutes)

START THE TABLEWARE-TO-GO CHALLENGE!

Welcome the club members. **Explain to kids:**

- *Your challenge is to find a new design for tableware that can be reused. People should also be able to carry them and keep them clean.*
- *Tableware describes the small tools that people use to eat: spoons, forks, knives, and chopsticks.*
- *In places where tableware is used, it can also be called silverware, cutlery, or utensils.*

Ask kids: *What are the different foods that you eat? What tools do you use to eat these different foods?* **Allow kids to discuss** their answers.

Show *The Design Process* poster and go over the steps with kids. Tell them they will start with the first step:

Define the Need (10 minutes)

If you have examples of plastic spoons, forks, and knives, or wooden chopsticks, give them to club members to pass around. **Ask kids:**

- *What are **single-use** spoons, forks, knives, and chopsticks? What does single-use mean?*

  If kids are unsure, say that
  - single-use products are also called "disposable."
  - they are used once and thrown away.
  - in some parts of the world, meals that people buy at stores and restaurants come with tableware that is single-use.
- What is single-use tableware made from?
  - Single-use plastic tableware is usually made from a kind of plastic called polystyrene, which is not recyclable. When the plastic goes into the ocean, it breaks into small pieces that have toxic chemicals. These small pieces can harm fish and other animals. If this plastic goes into landfills, it can add pollution to groundwater and rivers.
  - Chopsticks are usually made from wood, such as bamboo or poplar. When bamboo and poplar trees are cut down, it often harms animals by removing their habitats (places where they live). By removing the trees that hold the soil in place, it also harms the land by causing erosion (the land washes away in heavy rains).
  - Some tableware is compostable, meaning it breaks up within a few months when placed in a pile of natural materials like grass and food. Then, it provides nutrients to the soil. Compostable tableware is made from ingredients such as corn and wheat, and even sugar! Compostable tableware does not pollute the environment but it is more expensive than plastic tableware.

Talk with kids about **environmentally sustainable designs** for tableware:

- *Designers who make sustainable products think about the **life cycle** of the materials they use. What is a life cycle?*
- If kids seem unsure, tell them: *The life cycle of a material is the story of the material from how the material is made to where it goes when it is no longer used.*

Talk with kids about the life cycle of plastic. Hold up the plastic tableware you brought (or a plastic water bottle). **Say and ask:**

- *Everything has a life cycle. What material is this tableware made from?* (Plastic!)
- *Where did the plastic come from?* (The plastic is made from fossil fuels, like oil and natural gas. Companies get the fossil fuels by pumping them from the ground.)
- *What happens next with the oil or natural gas?* (After the oil and natural gas are made into plastic, that plastic is made into tableware—spoons, forks, and knives. Energy from fossil fuels power factories that make millions of pieces of plastic tableware.)
- *Then where does the tableware go?* (The tableware travels long distances around the world to stores, usually on big ships, which are also powered by fossil fuels.)
- *What happens after people and restaurants buy the tableware?*
  - People eat with the plastic spoons, forks, and knives and then throw them away.
  - Plastic tableware cannot be recycled.
  - This type of plastic lasts in landfills and oceans for more than 1,000 years before it decomposes.
- When a product is very popular around the world, and customers use and then throw away the product every day, a lot of material is needed to make new ones. And a lot of material is thrown away.

Tell kids: *As inventors, you are going to design tableware that is sustainable. Sustainable products can be manufactured and used again and again, causing less harm to the environment.*

Brainstorm and Design (10 minutes)

BRAINSTORM

Ask the whole group to brainstorm a new design for tableware that people can reuse, carry with them, and keep clean. Give kids more information and ask questions to help them think about a solution for designing tableware that is not single-use (something that is used once, then thrown away):

- *One way to prevent pollution and waste is to invent products that are **reusable** instead of single-use. Reusable products can be used again and again.*
- *Another way to make sustainable products is to use materials that cause less harm to the environment when they are created and thrown away. Engineers and inventors consider both the benefits and the problems of different materials at different stages of the materials' life cycles.*

- *What are the benefits of making single-use tableware from plastic?* (Examples are: low cost; easy to manufacture; often come wrapped in plastic or paper so people feel they are clean and safe to use.)
- *What is harmful about plastic? (*Plastic takes a long time to decompose in landfills or in the ocean. It creates pollution on land and in the ocean as it decomposes.)
- *What are the benefits of making single-use tableware from wood?* (Wood feels good and looks good. Wood is biodegradable: it breaks down into harmless pieces in the soil.
- *What is harmful to the environment about using wood?* (Single-use wood products are often made by cutting trees in a way that hurts animal habitats.)
- *What other materials could be used to make tableware?* (Metal, bone, glass, shell. Kids may suggest other natural or human-made materials.)
- *After spoons, forks, and knives are used, they need to be washed so that people do not get sick. How could you design sustainable tableware so it can be cleaned and kept clean when you carry it around?*
- *What are different types of food that people eat around the world? How could you design tableware so it could be used to eat different kinds of food?*
- *What device, carrier, or system could you invent for people to use to carry reusable spoons, forks, knives, and chopsticks? (*They could invent:
  - a new kind of eating tool that is easy for people to carry with them.
  - tableware from a sustainable material that is easy to carry.
  - a way for people carry their own tableware and keep it clean when they go to a restaurant to eat.)

Allow a few minutes for kids to talk about their answers. Some ideas might be for special carriers for tableware or different ways of making spoons and forks. Ask kids to briefly share their ideas with the group.

DESIGN

Show kids the materials in the Recycled Materials Box. **Give them drawing paper and pencils. Ask kids to work independently** to draw their designs. Ask kids to label the materials they would use (plastic, metal, natural materials).

Build (20 minutes)

Ask kids to form pairs or teams. Tell kids they will build a prototype for tableware that people can carry with them and keep clean.

Ask: *What is a prototype?*

If kids are unsure, say: *A prototype is a quickly-made, simple model for an engineer to test if their idea will work.*

Tell kids:

- *Look at your team members' design drawings and choose a final design. Pick the best features and ideas of each team member and put them together for your prototype.*
- *Pick materials from the **Recycled Materials Box** to build your prototype.*

Test and Evaluate (5 minutes)

Ask the teams to test and evaluate their prototypes' designs by walking around with them. Kids could pretend to take their prototype to a store or restaurant and sit down to eat.

Ask kids to present their prototypes and demonstrate how they function.

Ask and discuss:

- *What is the best feature of your design?*
- *What materials would the final product be made from?*
- *Where do these materials come from? What will happen to the materials when people throw the prototype away?*
- *How are these materials harmful or not harmful to the environment?*
- *What steps of the design process did you use? How did these steps help you improve your design?*
- *How did you test your design? What did you learn from testing?*

Redesign (10 minutes)

Redesign and test again.

Ask kids to clean up.

- **Let kids keep their prototypes, if possible.**
- Ask kids if you can **hold their brainstorm and design sketches** for the partner exchange.
- **Resupply your Recycled Materials Box** with the usable leftover paper and materials from the session.
- **Give each kid a sticker** for their membership card. **Collect the cards** or **ask kids to store their cards.**

Extension Activity: Suggest that kids show 1–3 people their designs, then interview the people about them. Kids can ask family members, peers (except club members), teachers, and other community members their opinions on the prototypes. Kids can ask what the people see the benefits and problems to be. Ask kids to take notes and report the feedback at the next club meeting.

DSG CLUB GUIDE CREDITS

The DSG Club Guide was produced by the Education Department at WGBH.

Seeta Pai
Executive Director

Sonja Latimore
Editorial Content Director

Robert Parks
Writer and Editorial Project Manager

Mary Haggerty
Director of Media Engagement

Saranya Sathananthan
Outreach Project Manager

Nicki Sirianni
Outreach and Digital Marketing Specialist

Priya Joyce
Intern

Petronella Gianocostas
Designer

Richard Sheppard
Illustrator

Wendy Windle
Illustrator

Marisa Wolsky
Executive Producer

Advisors

Troy Dassler
Professional Development Specialist,
Wisconsin Center for Educational Research,
University of Wisconsin-Madison, Madison, WI

Marcus Ginder
Program Director, GreenLearning,
Drayton Valley, Alberta, Canada

Amy Hoffmaster
Director of Program Innovation,
Citizen Schools, Boston, MA

Rich Lehrer
Director of Innovation,
Brookwood School, Manchester, MA
National Faculty,
Buck Institute of Education, Novato, CA

Mary McGrath
Executive Director, GreenLearning, Drayton Valley,
Alberta, Canada

Christopher Whitbeck
Principal, Douglas Elementary School, Douglas, MA

Manuela Zamora
Executive Director, New York Sun Works, New York, NY

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