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About this Manual

The Designing Our World (DOW) manual was written to guide program facilitators through behavioral, structural, and curricular aspects of the Designing Our World programs. These materials have been developed as a resource for museum and community educators.

This guide is divided into four sections:

Introduction:

- Project Goals
- The Engineering Design Process

Youth Activities:

- Icebreakers
- Discussion Guides
- Comprehensive Engineering Activity Plans
- Facilitation Guides

Adult/Community Engagement:

- Strategies and Resources for Engaging with Families
- Professional Development Modules

Additional Resources:

- Designing Your Program
- Strategies for Engaging Girls in STEM (Science, Technology, Math, and Engineering)
- Tips for Integrating Role Models
- Evaluation Resources
- Web and Print Resources

Goals of *Designing Our World*

The *Designing Our World* (DOW) project centers on STEM (Science, Technology, Engineering, and Math) equity and addresses the need for more youth, especially girls and those with diverse backgrounds, to pursue engineering-related careers and fill vital workforce gaps. We recognize that in order to drive innovation and collaborate globally, the United States needs a strong and creative engineering workforce. Training more engineers with diverse backgrounds and life experiences will advance this goal and maximize innovation. Through this project, we hope to empower a community of citizen engineers around the globe.

There's no shortage of engineering resources available for educators to use. How are the resources in this manual any different? *DOW activities were developed using research-based strategies shown to engage girls and other underrepresented groups in STEM.*

Specifically, DOW activities were designed to:

1. Introduce engineering role models, especially women and people of color

In order to combat stereotypes and to help all students imagine themselves as potential engineers, we took every opportunity to highlight real-life STEM practitioners. See for example, the video from mechanical engineer Caity Clark in “Energetic Ocean” and the print interview from bioacoustic engineer Elizabeth Küsel in “Sounds of the Sea.”

2. Base activities on real-world engineering problems

Rather than propose vague or arbitrary challenges, like “build the tallest tower!” DOW activities model real-world engineering problems. In “Smooth Travels,” for example, students are challenged to build a road that a wheelchair user could safely use. Just like real-life civil engineers, students have to consider how the grade, the sharpness of turns, and road materials would affect a person in a wheelchair.

3. Highlight a broad range of engineering careers

Most people know that engineers design buildings and bridges, but many are unaware of the breadth of career possibilities for engineers. DOW activities introduce students to lesser-known branches of the field, including biomedical engineering (“Surgical Solutions”), industrial engineering (“Get it Together”), and environmental engineering (“Pollution Solution”).

4. Promote collaboration

Research shows that girls prefer socially oriented activities. DOW activities are specifically designed to promote collaboration; in some cases, the goal is unattainable unless students work together. In “Get it Together,” for example, students have to design an assembly line process to put together model emergency supply kits. Success is measured by their ability, as a group, to increase their overall efficiency.

5. Highlight the ways engineering can be altruistic

Research shows that girls are drawn to engineering when they see how engineers help others. All DOW activities highlight ways engineers can help people in need, animals, or the environment. The activities “Save the Day” and “The Perfect Present,” in particular, challenge students to consider a specific user and design an innovation that would help that user.

6. Require iteration

“Iteration” refers to the process by which engineers test their design and then return—or iterate—to the drawing board to improve their design. There’s no “one right solution” to any DOW activity. Instead, challenges are designed so that students can constantly improve their design, just as real-world engineers do. So for example, in “Zip Line Rescue,” once students solve the initial challenge of moving a figurine down the zip line, the facilitator can offer additional prompts—such as, “Can you make it go slower? Can you develop a way to pull the figurine back to the top?”—to get students iterating.

7. Engage the whole community

The engineering activities in this manual don’t stand alone; the DOW program is designed to engage adults and community partners in order to create an educational model that supports cross-context learning and engagement through multiple experiences. See “Adult Engagement” and “Additional Resources” sections of this manual for information on how to train and engage adults to participate in youth engineering development.

The Engineering Design Process

Designing Our World Definition of Engineering:

From sewing to spaceships, engineering is a collaborative, creative process that solves problems for people and improves our world. You can use the engineering process to approach problems in your everyday life: Ask, Imagine, Plan, Create, and Improve. Sharing and collaboration throughout the process can enrich the results and enhance the experience.

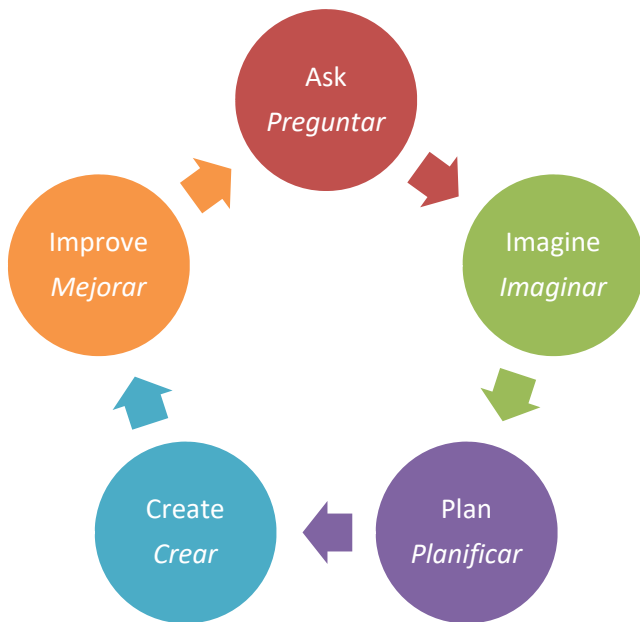
The engineering design process is the approach that engineers use to solve problems. It is a series of steps that help guide how engineers think while designing a solution. There are many versions of the engineering design process, but we are using the steps as defined by *Engineering is Elementary*, developed by the Museum of Science, Boston. To begin the **engineering design process**, engineers must first **ask** a question, **imagine** a solution, **plan** a design, **create** a model and test it, then **improve** their original design based on the results of the test. Testing and improving a design inspires more questions, and the process begins again!

Something important to remember about activities that use the engineering design process is that they are **iterative** and that they have **no one answer**. The activities in this manual are iterative because they require participants to test and improve their designs multiple times to make them better. The solutions to the problems posed in these activities are as vast as the imaginations of your students!

On the following page you will find a description of the Engineering Design Process in both English and Spanish. You can use this page to discuss the process with youth or adult audiences. As students participate in engineering activities, draw connections to the work they are doing and the engineering process.

Engineering Design Process

Proceso de diseño de ingeniería



Engineering design cycle adapted by the *Head Start in Engineering* team, with permission from the *Engineering is Elementary* project, Museum of Science, Boston.

Ask—Ask questions to understand the problem and what you need to solve it.

Pregunta—Haz preguntas para entender el problema y qué necesitas para resolverlo.

Imagine—Brainstorm as many possible solutions and designs as you can.

Imagina—Piensa en la mayor cantidad de soluciones y diseños que puedas.

Plan—Pick a design and decide how you will use your materials.

Planifica—Escoge un diseño y decide cómo usarás los materiales

Create—Build and test your design to see how well it solves the problem.

Crea—Construye y pon a prueba tu diseño para ver qué tan bien soluciona el problema.

Improve—Make changes to your design based on what you learned.

Mejora—Cambia tu diseño en base a lo que aprendiste.

The **engineering design process** is a cycle that engineers follow to create and test solutions to a problem. We also use this process to solve problems every day, like figuring out a food recipe or building a bookshelf. Talking about the engineering design process with students and using the steps when you work on problems is a great way to get learners interested in engineering and help them develop problem-solving skills.

El proceso de diseño de ingeniería es un ciclo que los ingenieros siguen para experimentar y encontrar soluciones a un problema. Utilizamos este proceso para resolver problemas todos los días, desde preparar una receta de cocina, hasta armar un estante de libros para la habitación de los niños. Cuanto más comprendemos y hablamos acerca de este proceso, más probabilidades tienen nuestros niños de incorporar este proceso y su vocabulario en la resolución de problemas.

Engineering Mindset

The activities in *Designing Our World* not only encourage the use of the engineering design process, they also highlight an engineering mindset that students can use to be successful in many different real-world contexts. The attitude students bring to solving a problem, and the strategies they use to solve it, can influence the outcome as well as the level of enjoyment associated with the process. In addition to hands-on engineering activities, this manual also includes icebreaker suggestions and discussion guides covering aspects of an engineering mindset that can be incorporated into sessions.

The key components of an engineering mindset are:

Persistence

Good engineering activities involve several rounds of iteration and open-ended solutions, which can be frustrating for students who want to “finish” and “get the right answer.” Persistence involves a willingness to try something that might not work, evaluating what went wrong, and then trying again and again. Students also demonstrate persistence when they seek out new ways to improve their design even after it has accomplished its primary goal.

To encourage persistence, facilitators should:

- Highlight “unexpected results” over failures
- Use their personal experiences, the experiences of role models, and anecdotes to show that trying, failing, and trying again is common and part of the process
- Brainstorm techniques to overcome frustration and strategies for getting unstuck
- Praise students’ “can do!” attitudes and resilience instead of praising their success at meeting a goal

Altruism

The limitations of a classroom setting mean that a lot of engineering activities are very symbolic. Even if your materials are cardboard, straws, and binder clips, good activities need to respond to a real-world engineering problem. Children, especially girls, are more invested in a problem if they understand and care about the need for a solution. “Build a ramp for wheelchairs and strollers!” is much more compelling than “Make the ball go from here to there!”

To encourage altruism, facilitators should:

- Humanize engineering activities. One way to do so is by including human figurines where applicable, or by emphasizing how solving a particular problem will help people, animals, or the environment

- Personalize the activity with problems that facilitators or students have faced
- Encourage students to make connections and apply engineering skills to other parts of their lives
- Include stories and activities from a broad range of engineering careers. Highlight ones that are more surprising (e.g., biomedical, environmental, material engineering, etc.)
- Emphasize how each field of engineering works to help people and/or animals

Collaboration

The stereotypical image of an engineer is often someone who works alone. However, collaboration is an integral part of the engineering process, and engineers often work with all sorts of people. Sharing ideas, building on the work of others, and expressing one's own ideas clearly are lifelong skills that are developed through collaborative work. The goal of creating a supportive and collaborative atmosphere is that students seek to work with one another to solve problems without prompting from a facilitator.

To encourage collaboration, facilitators should:

- Favor activities in which collaboration is necessary for success
- Avoid competition; work toward a shared goal instead, or encourage students to compete to improve on their own best
- Share stories about how people with different areas of expertise can collaborate on a project
- Model respectful communication and discuss norms of communication with students
- Encourage students to observe other groups to get ideas while working on engineering problems; emphasize that this is *not* cheating!

Table of Contents

In this section you will find detailed guides for facilitating icebreakers, discussions, and hands-on design challenges for youth grades 3-8. Each document includes learning objectives, set-up and supply requirements, a step-by-step guide to facilitating the activity, printables (where applicable), and relevant background information.

Facilitation Tips

Tips for facilitating engineering activities and for using this manual; list of basic building supplies.

Icebreakers

Quick group activities to promote creative thinking and collaboration.

Discussion Guides

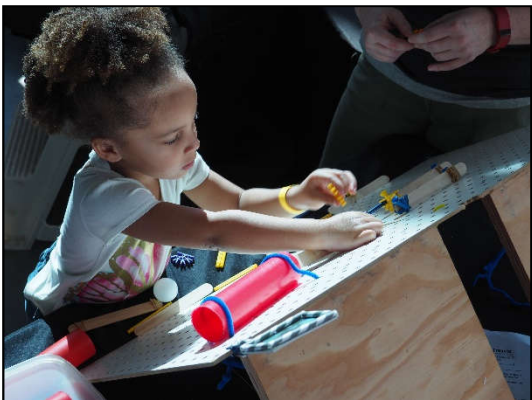
- Who is an Engineer?..... *Address biases about women and people of color in STEM fields. Explore the many types of engineering careers.*
- Dealing with Frustration... *Brainstorm how to deal with failure and manage emotions. Develop strategies for what to do when stuck.*
- Fixed vs. Growth Mindset *Build persistence and a “can do” attitude. Explore the science behind how brains grow and change.*

Engineering Activities

- Save the Day..... *Design an imaginary object to help someone in a disaster. Revise the design to include constraints.*
- Zip Line Rescue..... *Design a carrier to transport an injured person down a zip line.*

Continued on next page →

- Pollution Solution..... *Create model neighborhoods that incorporate green spaces, such as bioswales and parks, to prevent pollution from flowing into a river.*
- Shake, Don't Break..... *Determine the effectiveness of various materials at isolating the base of a structure during a simulated earthquake.*
- Smooth Travels..... *Design an accessible path that will allow for the slowest, safest route possible down a mountain.*
- Energetic Ocean..... *Design a model offshore wind and wave energy farm to maximize the amount of energy the farm can produce.*
- Sounds of the Sea..... *Engineer a way to hold different objects underwater at a particular depth.*
- Surgical Solutions..... *Create specialized instruments for different types of surgery.*
- Get it Together!..... *Plan an efficient assembly line process to put together emergency supply kits.*
- Cool it Down..... **Museum-Based Activity:** *Design pathways to cool down a stream of water so that it can be safely returned to a river.*
- The Perfect Present..... *Design and improve a gift based on a classmate's individual needs and unique interests.*



Tips for Facilitating Engineering Activities

The engineering design process is a unique kind of learning experience for both students and teachers. Unlike with traditional learning experiences, in engineering, there's no one "right" answer; sharing is encouraged; failure is celebrated; and "success" is relative. The following facilitation tips apply to *all* of the engineering activities included in this manual, and will help you and your students have a positive experience.

1. Make the objective clear

Engineers set out to meet a specific objective. For example, in the Zip Line Rescue activity, the goal isn't just to tinker around with strings and paperclips; the goal is to safely move the figurine from the top of the zip line to the bottom—just like rescuers would do in a real-life emergency situation. It can be helpful to write the objective on the board or large poster to help students stay focused.

Additionally, if there are specific constraints students tend to forget (for example, they cannot use their hands to guide the figurine down the zip line), make those constraints clear, too.

2. Encourage Sharing of Ideas

Remind students that it is perfectly okay—and even encouraged—to look at and utilize other students' ideas. All the best engineers have studied the ideas and innovations of other engineers, copying, adapting, or improving them as necessary. There's no such thing as "cheating" in engineering!

**Go ahead,
steal ideas!**

3. Test Early, Test Often

Students will often get so wrapped up in building, they will forget to test their design to see if it meets the objective. For example, a student might spend 45 minutes painstakingly building a rig for their zip line, and then upon testing it for the first time, find that it doesn't work. Remind students to build a little, then test, then build a little more, then test again, making modifications all along. This is how real-world engineers work, too.

4. Celebrate Failure

Failure is fantastic!

Students may feel frustrated when their designs don't immediately meet the objective. You may hear discouraged refrains of "It didn't work!" or "It broke!" Model a cheerful and curious attitude towards failure: "Hmm... I wonder what you could change to keep that rig from falling of the zip line?" Remind students that engineers often have to try many, many different designs before developing one that works. And every time you fail, you learn something new, bringing you closer to your goal. See discussion guide "Dealing with Frustration" (in this manual) for more ideas on moving past "failure."

5. Resist the Urge to "Help"

As an adult, it can be difficult to watch a child struggle with an engineering challenge, especially if the "solution" seems clear to us. It's so tempting to reach in to make a little adjustment, or offer a little advice to help them along. In doing so, however, we rob children of the opportunity to struggle and to figure things out on their own. Instead of advice, offer observations and/or questions. "I notice that your zip line rig tends to get tippy right about *here*." Or, "I'm wondering whether a lighter or heavier rig would be more stable. What do you think?" For more ideas on how to facilitate without "helping," see the Facilitation Guide at the end of each activity.

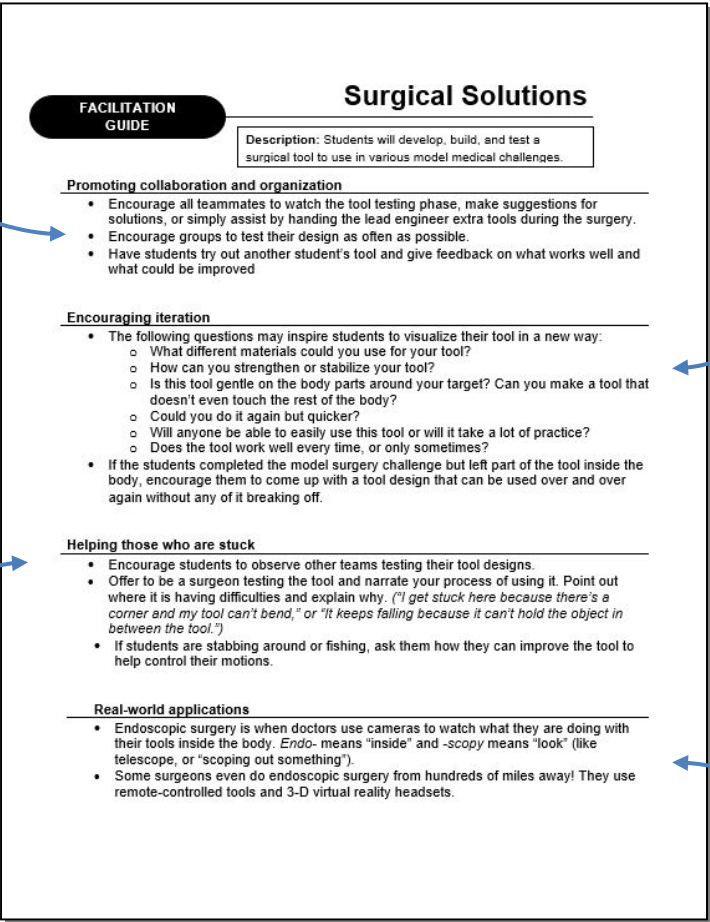
For even more tips on facilitating engineering activities—including how to tailor experiences to engage girls in particular, see the "Adult Engagement" and "Additional Resources" sections of this manual.

Note on Facilitation Guides

At the end of each engineering activity, there is a one-page facilitation guide designed to be used as a quick reference for facilitators and other helpers during the activity session. Make copies of this guide to have on hand for visiting role models, instructor assistants, and facilitators who are new to the activity. Facilitation guides include troubleshooting tips specific to each activity.

Classroom strategies to promote collaboration and organization

Questions to encourage further thinking and promote iteration for students who feel they have completed the activity



The image shows a sample facilitation guide titled "Surgical Solutions". It is organized into several sections with bullet points and sub-sections. The sections are: "Promoting collaboration and organization", "Encouraging iteration", "Helping those who are stuck", and "Real-world applications". Each section contains specific instructions and questions for facilitators to use during the activity.

FACILITATION GUIDE

Surgical Solutions

Description: Students will develop, build, and test a surgical tool to use in various model medical challenges.

Promoting collaboration and organization

- Encourage all teammates to watch the tool testing phase, make suggestions for solutions, or simply assist by handing the lead engineer extra tools during the surgery.
- Encourage groups to test their design as often as possible.
- Have students try out another student's tool and give feedback on what works well and what could be improved.

Encouraging iteration

- The following questions may inspire students to visualize their tool in a new way:
 - What different materials could you use for your tool?
 - How can you strengthen or stabilize your tool?
 - Is this tool gentle on the body parts around your target? Can you make a tool that doesn't even touch the rest of the body?
 - Could you do it again but quicker?
 - Will anyone be able to easily use this tool or will it take a lot of practice?
 - Does the tool work well every time, or only sometimes?
- If the students completed the model surgery challenge but left part of the tool inside the body, encourage them to come up with a tool design that can be used over and over again without any of it breaking off.

Helping those who are stuck

- Encourage students to observe other teams testing their tool designs.
- Offer to be a surgeon testing the tool and narrate your process of using it. Point out where it is having difficulties and explain why. (*"I get stuck here because there's a corner and my tool can't bend," or "It keeps falling because it can't hold the object in between the tool."*)
- If students are stabbing around or fishing, ask them how they can improve the tool to help control their motions.

Real-world applications

- Endoscopic surgery is when doctors use cameras to watch what they are doing with their tools inside the body. *Endo-* means "inside" and *-scopy* means "look" (like telescope, or "scoping out something").
- Some surgeons even do endoscopic surgery from hundreds of miles away! They use remote-controlled tools and 3-D virtual reality headsets.

Ideas to encourage those who are stuck or having a hard time moving forward

Background information and examples that emphasize real-world applications, altruism, and careers

Basic Building Supplies

These are the basic building supplies that are used repeatedly in the activities in this manual. They can be substituted or omitted based on what you have available, but students should have access to a variety of materials they can choose from. Buy in bulk to have extras and reduce costs!

Suggested Building Materials

Rubber bands	Pipe cleaners
Wooden craft sticks	String
Tongue depressors	Sticky tack
Paper straws	Bamboo skewers
Cardboard	Clothespins
Cardstock or cereal boxes	Twist ties
Craft foam sheets	Plastic containers for storage
Paper clips	Plastic sandwich bags
Binder clips	Scrap paper
Brads	

Notes on Materials

Follow these simple tips to reduce stress, mess and environmental impact!

- **Reduce, Reuse, Recycle:** Limit the number of materials students have to work with initially, reuse those that are salvageable, and recycle the rest in the classroom or at your local recycling center.
- **Limit Tape and Glue:** We do not recommend providing students with tape or glue, since their use can prevent iteration by locking a design in place. Tape and glue are also difficult to clean up. In most situations, rubber bands, binder clips, clothespins, sticky tack, and other fasteners work just as well, if not better.