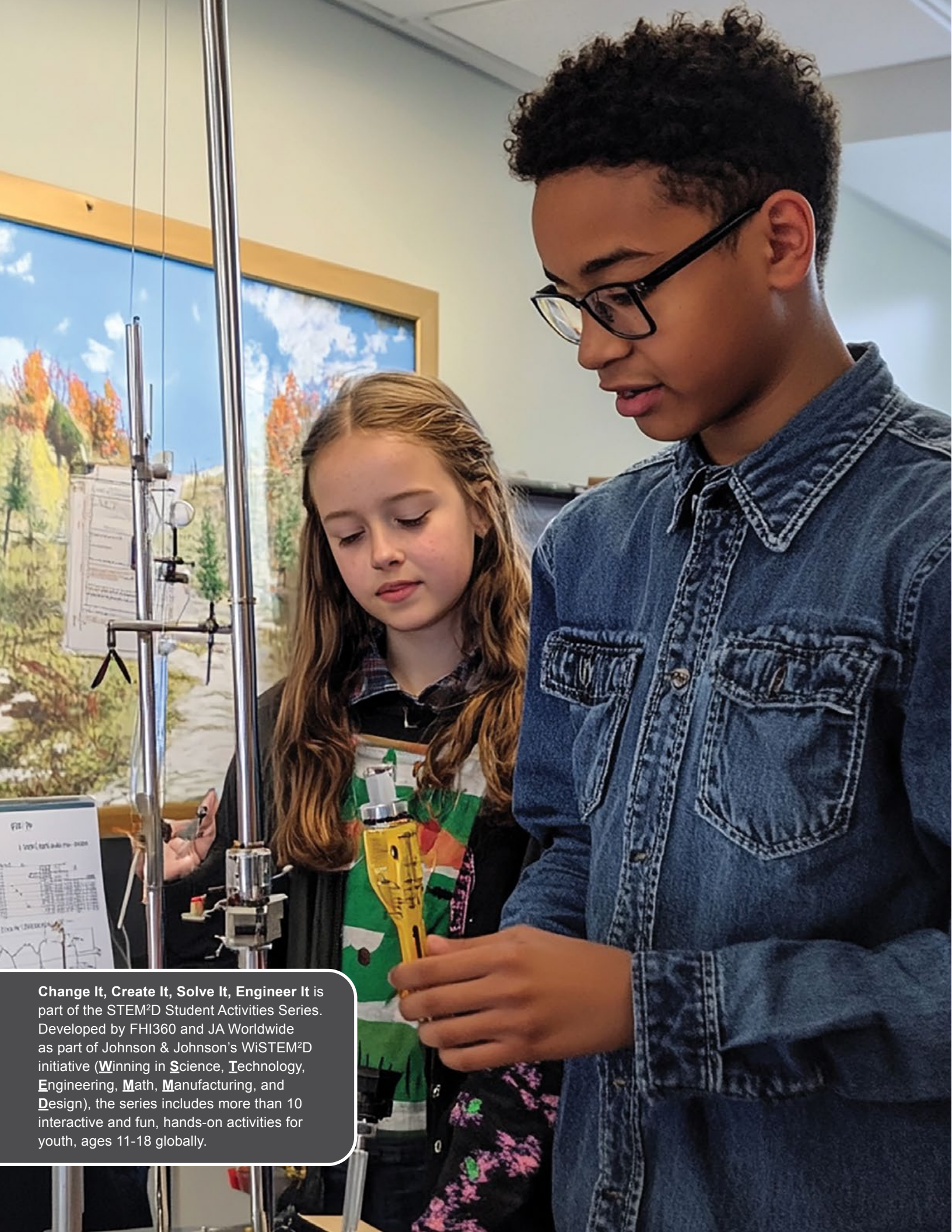


CHANGE IT, CREATE IT, SOLVE IT, ENGINEER IT

**STEM²D Topics:
Engineering,
Technology, and Design**

**Target Population:
Students, ages 11-14**



Change It, Create It, Solve It, Engineer It is part of the STEM²D Student Activities Series. Developed by FHI360 and JA Worldwide as part of Johnson & Johnson's WiSTEM²D initiative (**W**inning in **S**cience, **T**echnology, **E**ngineering, **M**ath, **M**anufacturing, and **D**esign), the series includes more than 10 interactive and fun, hands-on activities for youth, ages 11-18 globally.

CHANGE IT, CREATE IT, SOLVE IT, ENGINEER IT

STEM²D Topics: Engineering, Technology, and Design

Target Population: Students, ages 11–14

ACTIVITY DESCRIPTION

Students practice engineering design. They begin to recognize that technologies and new innovations result when engineers apply science and math principles to design and develop products, structures, machines, tools, or systems that improve everyday life.



ESTIMATED TIME

This activity typically takes **45–60 minutes** to complete and should be conducted in one session.

STUDENT DISCOVERIES

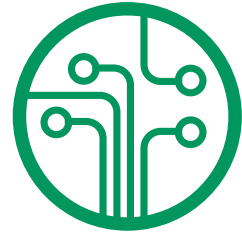
Students Will

- Participate in a team-based learning experience.
- Learn how STEM²D-science, technology, engineering, math, manufacturing, and design-subjects are involved in engineering design.
- Develop important STEM²D skills, such as defining problems, testing and refining possible solutions based on criteria and constraints, in order to develop an optimal solution.
- Recognize that STEM²D offers diverse and exciting career opportunities.
- Have fun experiencing STEM²D.

GETTING READY

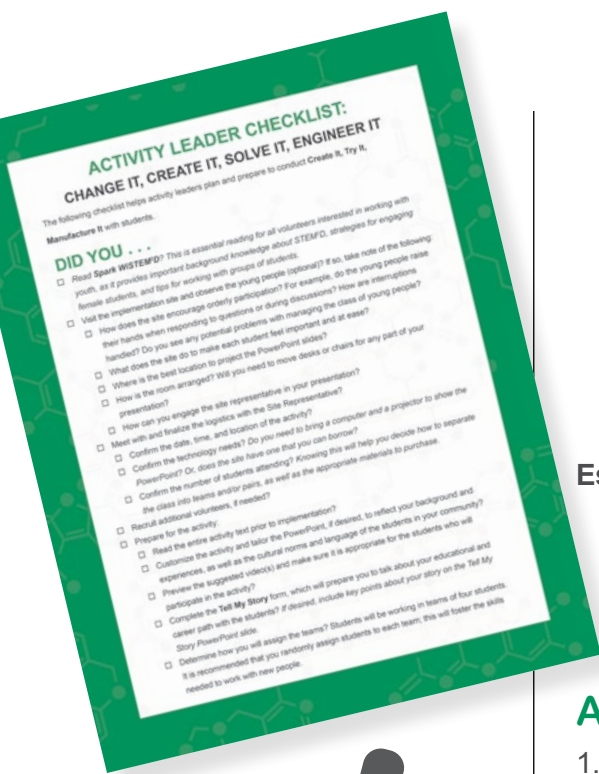
Materials

- Computer with projector, and Internet access.
- PowerPoint: Change It, Create It, Solve It, Engineer It
- Activity Leader Checklist
- Tell My Story Form



STEM²D Skills

- Construct Explanations
- Engineer Solutions
- Evaluate Information
- Creativity
- Critical Thinking
- Decision Making
- Problem Solving
- Teamwork



- Student Handout (1 per student)
- Copy paper (5-10 sheets per team)
- Pencils
- Crayons (optional, Learning Game Concept)
- Markers (optional, Learning Game Concept)
- Colored pencils (optional, Learning Game Concept)

Estimated Material Cost:

Activity leaders can expect to incur \$10.00 U.S. Dollars (excluding optional items) in materials costs when completing this activity with 20 students organized into teams of four students.

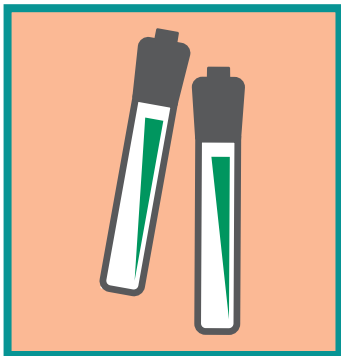
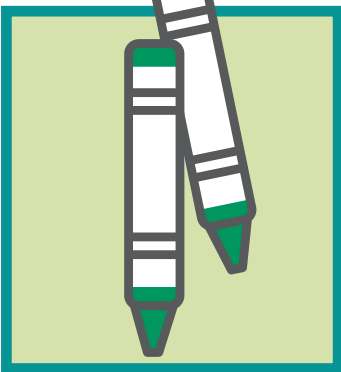
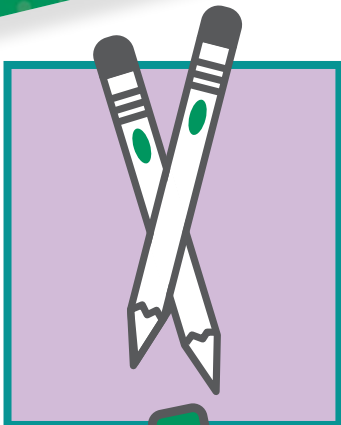
Activity Leader Preparation

1. Read **Spark WiSTEM²D?** This is essential reading for all volunteers interested in working with youth, as it provides important background knowledge about STEM²D, strategies for engaging students, and tips for working with groups of students. Download at STEM2D.org.
2. Review the **Change It, Create It, Solve It, Engineer It Activity Leader Checklist** for details and specific steps for planning and preparing to implement this activity.
3. See the **STEM²D Student Activities Series Overview** for additional information.

STEP-BY-STEP ACTIVITY: CHANGE IT, CREATE IT, SOLVE IT, ENGINEER IT

1. Welcome and Introductions (15 minutes)

- Greet the students.
- **(Tell My Story Slide)** Begin the PowerPoint. Tell the students your name and your organization/company. Talk about your educational and career path. Use the Tell My Story form as the basis for your remarks. Be prepared to describe your job or a typical day, and provide information about your background including:
 - Your education—focus on secondary and postsecondary classes and courses
 - Current work projects



- Interests and hobbies
- Why you love STEM²D, and how your work is connected

Write your introduction ideas here.

- Ask the students and any volunteers helping today to introduce themselves.
- Use the Conversation Starters to learn more about the students and their interests.
- **(Today's Plan Slide)** Review Today's Plan. Tell the students that engineers can change the world. Their work shapes the future and impacts every aspect of our daily lives.
- **(Innovations Slide) Engineering** is the practical application of science and math skills to everyday life. Engineers are trained and skilled in the design, construction, and use of machines or systems in any of the many branches of engineering (civil, chemical, electrical, mechanical). **Engineers** help people by applying science and math principles to design and develop products, structures, machines, tools, or systems that improve everyday life.
- Explain that today they will use a specific process to solve problems and develop solutions just like engineers do every day.
- Define **innovation** (an improvement of an existing product or method) and review the innovations listed. Distribute the Student Handouts and ask the students to consider what each of the items presented on the PowerPoint have in common. Encourage them to use their handouts for notes, comments, and ideas.
 - Do not be concerned if the students are not familiar

CONVERSATION STARTERS: CAREER PLANNING

- When you consider your future, what are you most excited about?
- Do you see yourself working for others, for a large company, with your friends, for yourself? Why or why not?
- What does the perfect work day look like to you? Are you outdoors? Are you working alone, or with others? Do you solve problems? Do you fix or build things?

TIPS FOR STARTING CONVERSATIONS:

Conversation Starters are provided throughout and include questions designed to introduce students to the activity topics. Use the questions—modify them, or add others—to engage your students.

KEY WORDS

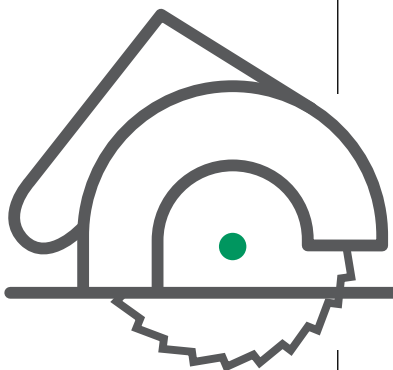
- Engineering
- Engineers
- Innovation



➤ Engineers are trained and skilled in the design, construction, and use of machines or systems in any of the many branches of engineering.

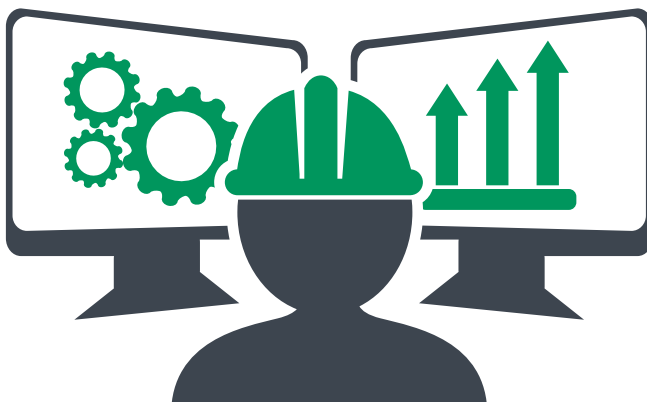
with all of the innovations.

- Allow the students a minute or two to review the list and record their ideas. Have the students turn to someone sitting near them and review their ideas with a partner.
- Ask for volunteers to share their ideas. Encourage all responses.
- **(Innovations Explained Slides)** Review the information provided about each innovation. Explain that one commonality is that all of the innovations listed were developed by engineers to solve a problem using what they knew about the natural world and human behavior.
- Tell the students that engineering is problem solving. Encourage them to consider how many times a day they solve problems, build something, use tools, design a solution, draw a figure, use math, or improve something. Each time they do they are thinking and performing like an engineer.



2. Define Engineering Design (5–10 minutes)

- Explain that engineers follow a process to solve problems. The engineering design process is a great way to tackle almost any task. We use it when we create something that did not exist before, or when we plan a trip, cook a meal, choose what to wear, or when we determine what to buy from many options.
- **(Engineering Design Process Slide)** Have the students follow along on their handout as you describe the steps (component ideas) involved in engineering design, as well as the designing solutions information.
- Explain that the engineering design process is used by scientists and engineers to define problems, and test and refine possible solutions based on criteria (clear purpose) and constraints (limitations), in order to develop an optimal solution.
- The engineering design component ideas are included in the Engineering Design Process Chart reproduced in this activity as well as the PowerPoint to assist you with the introduction.
 - **DEFINE** engineering problems. Clearly state the problem, determine the criteria for success (Are we seeing the expected results?), and figure out the external constraints or limits (costs, time limits, resources, things to consider up front).
 - **DESIGN** solutions to engineering problems. Generate a number of different possible solutions (**brainstorm**), then evaluate potential solutions to see which ones best meet the criteria and constraints of the problem.
 - **OPTIMIZE** the solution. This involves systematically testing and refining. The final design is improved by trading off less important features for those that are more important.



TIPS FOR WORKING WITH STUDENTS

Secondary students (ages 11–14) begin to sharpen the focus of problems, determine more precise criteria and constraints, and take into account the larger context within which the problem is defined. Students can be expected to use systematic methods to compare and even combine different solutions as well as test and revise solutions multiple times to determine an optimal design.

TIPS FOR WORKING WITH STUDENTS

An engineer's initial ideas rarely solve the problem. Engineers must try different ideas, learn from the mistakes, and then try again.

When working with students and introducing engineering design, use the questions provided to tie their work to the specific steps in the process.

STUDENT QUESTIONS AND CONSIDERATIONS: DESIGN

Brainstorm

- What are some different ways to tackle this problem?
- How creative can you be?
- Off-the-wall suggestions often spark amazing ideas.

Evaluate

- Which brainstormed ideas are really possible, given the constraints you identified?
- What are some problems you need to solve as you build your solution?
- How can a sketch help clarify your design?

STUDENT QUESTIONS AND CONSIDERATIONS: SHARE SOLUTIONS

- What is the best feature of your design? Why?
- What are the steps you took to get your idea/product to work?
- What was the hardest problem to solve?
- Did you do anything more than once? What?
- If you had more time, how would you improve your design/prototype.

Engineering Design Process

DEFINE THE PROBLEM

Clearly state the problem to solve.



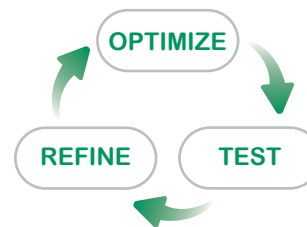
DETERMINE CRITERIA AND CONSTRAINTS

Consider the criteria (clear purpose, expected results) and constraints (costs, time limits, resources) that should be considered up front.



DESIGN

Generate (brainstorm) a number of different possible solutions, then evaluate potential solutions to see which ones best meet the criteria and constraints of the problem.



SHARE SOLUTIONS

► Point out that the component ideas do not always follow in order. Problem-solvers can redefine the problem or generate new solutions when ideas just are not working out.

3. Practice Engineering Design (15 minutes)

Try It: Paper Airplanes

- Emphasize that engineers use their understanding of the natural world, personal creativity, and **technical skills** to develop solutions to problems and create new and innovative solutions.
- Engineers work in teams. Often engineers assemble teams whose members have different skills and talents to help them develop solutions. The skills in highest demand are technical skills related to STEM²D (science, technology, engineering, math, manufacturing, and design). People with technical skills have the ability to perform a specialized task. By using these varying skills and the engineering design process, engineers and their teams create solutions and products people want to use.
- Separate the students into teams of product engineers (four to five students per team). Tell the teams they will practice using engineering design to build a paper airplane. Have teams follow along on their handouts as you go through the following activity steps:
 - **(Airplane Challenge Slide)** Define the problem (design a paper airplane that flies the farthest) with the teams. Share the determined criteria and constraints provided on the PowerPoint. Distribute five pieces of copy paper to each team.
 - Explain that teams will have 10 minutes to prototype different options before submitting one design to fly in the competition between teams.
 - Allow 10 minutes for the teams to design, test, refine, and test again their planes. Call time. Have each team fly their optimized design and determine which design flies the farthest.
 - Allow 5 minutes for teams to share their solution explaining which design worked best and why.
 - If students need additional practice, redefine the problem and establish new criteria and constraints. Have the teams test new designs and share their solutions.

KEY WORDS

- **Brainstorm**
- **Technical Skill**

TIPS FOR STARTING CONVERSATIONS: CREATIVITY

Ask the students to turn to a partner and tell them the name of a game they like to play. It can be a made up game, an electronic game, or a board game. Then have them tell their partner one way they would improve the game. Have them explain the change or improvement they would make to the game. Have the students complete the statement, "It would be the best game if _____."

TIPS FOR WORKING WITH STUDENTS AND STARTING CONVERSATIONS:

Engineering Design

- Provide support to the teams as necessary, move around the learning space to ensure participation from all team members.
- As appropriate, ask the following open-ended questions to help teams work through the process:
 - What are some different ways to tackle this problem?
 - How creative can you be?
 - What are some problems you need to solve as you build your solution?

- **Activity Leader Decision Point.** If time permits, or if you are working with students who are familiar with the engineering design process and want to explore another challenge, complete the Learning Game Concept activity.
- Otherwise move ahead to the Student Reflection section and wrap up the activity using the reflection questions provided.

4. Practice Engineering Design: (20 minutes)

Learning Game Concept

- Tell the teams that an exciting industry is game development. Product engineers develop games people like to play as well as games that teach people new or difficult concepts. Use the Conversation Starter to get students talking to each other.
- After a minute of sharing ideas, get the students' attention and tell them it is time to work together in teams to develop a learning game concept.
- **(Game-Concept Challenge Slide)** Consider reviewing the background information provided about the board game, Monopoly. Explain it was created in the early 20th century and was first known as The Landlord's Game. Its creator, Elizabeth Magie Phillips was an economist who wanted to teach people a difficult economic concept.
- Another Try It. Ask the teams to take a minute to consider the suggested science and math skills provided in the Try It section on their handout. Have teams select one skill from the list.
 - Encourage teams to consider other science or math skills for their game concept, but remind them they have a time constraint to consider.
 - What research does the team need to do to build a learning game addressing this skill?
- Tell the teams they will have 15 minutes to create a game concept that teaches young children one of the suggested science or math skills provided. The game concepts should show children a fun way to investigate the world around them, or demonstrate how math is used every day.

- Instruct the teams to complete the following engineering design steps included on the handout:
 1. Define the problem.
 2. Determine criteria and constraints. Teams will have 10 minutes to design a solution using limited resources, copy paper, and writing utensils (pens, pencils, markers, crayons anything the students have access to in the learning space).
 3. Design and evaluate potential solutions to determine which solutions best meet the criteria and constraints of the problem. As part of the design, create a sketch and identify possible materials needed to build the game.
- Allow 5 minutes for teams to conduct user testing with students from their team or another team to evaluate and redesign their learning game concept.
- Allow another five minutes for the teams to present their best game concept (optimal design) by responding to the following questions:
 - How does the concept meet the team's criteria for success?
 - What is the game's best feature? Why?
 - What was the hardest problem to solve? Why?

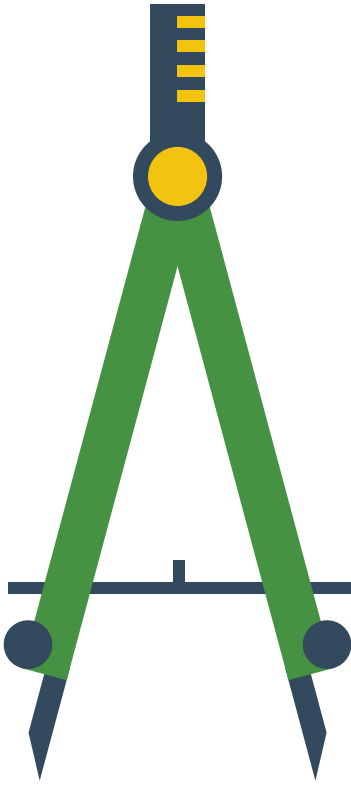
5. Student Reflection (5 minutes)

- **(Reflection Slide)** Wrap up the activity by asking the following student reflection questions:
 - How do engineers help people?



➤ Monopoly's creator, Elizabeth Magie Phillips was an economist who wanted to teach people a difficult economic concept.





- How is creating a game or creating a paper airplane an example of engineering?
 - Why is it necessary to determine criteria and constraints when defining a problem?
 - What would you change about your paper airplane or learning game concept if you had time to test it again?
 - If you had the opportunity to explain why STEM²D skills are important to achieving your ultimate career goal, what would you say?
 - Did your original thinking about STEM²D careers and professionals change? Why or why not?
 - Can you see yourself working in STEM²D? Why or why not?
- Thank the students for their efforts and participation, and congratulate them on completing this activity. Encourage the students to continue building their science and engineering skills. Reassure them that they can do STEM²D!

Extended Learning

Here are a few ways to extend the learning:

- Have the students develop a prototype for their game using their sketches and materials lists. Allow time for the teams to test, evaluate, and refine the complete prototype in order to come up with an optimal design.
- Have teams develop a game concept for young people that teaches a more challenging concept or more difficult skill.
- Investigate gender bias at the toy store. Take a walk through a toy aisle or investigate STEM²D toys online. Record your observations and consider the way toys are marketed to young girls compared to young boys. Is there a difference?
- Check out these two companies—both started by engineers—that provide youth with the opportunity to learn about physics and engineering. Both companies encourage learning through play and exploration.
 - Roominate Toys
 - Goldie Blox

Key Words

Brainstorm. A formal process to generate ideas: each person in turn, no discussion until all ideas are gathered, someone keeps the list, and people try to group the ideas.

Engineering design process. Used by scientists and engineers to define problems, and test and refine possible solutions based on criteria and constraints, in order to develop an optimal solution.

Engineers. People trained and skilled in the design, construction, and use of machines or systems in any of the many branches of engineering (civil, chemical, electrical, mechanical).

High-demand, high-growth careers. Occupations predicted to have more positions available than qualified applicants over the next 10 years.

Innovation. An improvement of an existing product or method.

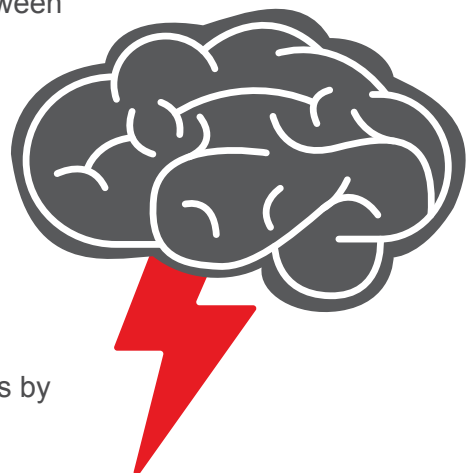
Prototype. An early model or experiment to rapidly create solutions to challenges and problems.

Resources. Materials engineers use to develop solutions people use.

- Capital resources: buildings, tools, machines, and money used to make products or provide services.
- Human resources: people who do the work needed to make products or provide services.
- Natural resources: things needed to make products or provide services that occur naturally, such as air, water, minerals, and trees.

STEM²D. An acronym that refers to science, technology, engineering, math, manufacturing, and design.

- **Science:** Observing, studying, and experimenting to better understand the natural world and how it works.
- **Technology:** Putting science and other knowledge to practical use to solve problems, invent useful tools, envision new possibilities, and establish meaningful connections between people and the world that surrounds them.
- **Engineering:** Applying science and math principles to design and develop products, structures, machines, tools, or systems that improve everyday life.
- **Math:** Using a quantitative framework (numbers, quantities, shapes, abstract principles, and problem solving) to describe the world.
- **Manufacturing:** Creating something from raw materials by hand or by machinery.



- **Design:** Creating, constructing, or inventing an object, plan, product, or system; it is also a human-centered mindset and collaborative approach that results in better experiences by uncovering unmet needs and championing meaningful relationships through user-friendly products, environments, and systems.

Technical skill. The ability to perform a specialized task well.

Tinker. Learning by creating and continuously refining and improving the creation. Tinkering is a driver of creativity, excitement, and innovation in STEM²D learning.

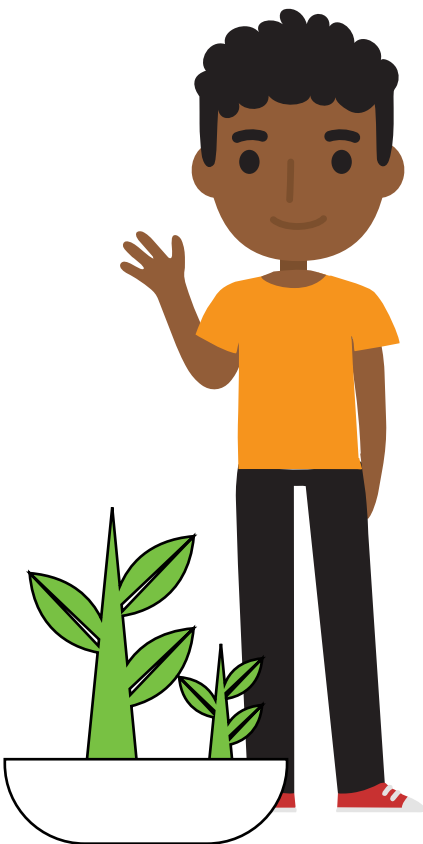
Activity Leader Reflection

After completing the activity, take a few moments to reflect on the following questions about implementing this activity:

- What went well and what could be improved? What would you do differently next time?
- How comfortable did you feel talking about STEM²D including: the engineering design process?
- Do you have a better understanding of STEM²D concepts?
- How useful was the information presented in **Spark WiSTEM²D** to implementing this activity?
- Will you volunteer for this type of experience again?

Resources and References

- Activity concepts and real-life connections provided by Ellen Oh, Global Strategic Design Office, and Binyah Kesselly, J&J Supply Chain, Johnson & Johnson.
- Design Squad Global:
<http://pbskids.org/designsquad/parentseducators/index.html>
- Engineer Girl
<http://www.engineergirl.org/4447.aspx>
- Stanford University: Criteria for experiments
<https://web.stanford.edu/group/Urchin/exp1.htm>
- Women Inventors
<http://www.women-inventors.com/Stephanie-Kwolek.asp>
- Mosathce, Harriet S., Laner, Elizabeth K., and Matloff-Nieves, Susan. (2016 *Breaking Through! Helping Girls Succeed in Science, Technology, Engineering, and Math*) Texas: Prufrock Press Inc.



ACTIVITY LEADER CHECKLIST:

CHANGE IT, CREATE IT, SOLVE IT, ENGINEER IT

The following checklist helps activity leaders plan and prepare to conduct

Change It, Create It, Solve It, Engineer It with students.

DID YOU . . .

- Read **Spark WiSTEM²D**? *This is essential reading for all volunteers interested in working with youth, as it provides important background knowledge about STEM²D, strategies for engaging students, and tips for working with groups of students.*
- Visit the implementation site and observe the young people (optional)? If so, take note of the following:
 - How does the site encourage orderly participation? For example, do the young people raise their hands when responding to questions or during discussions? How are interruptions handled? Do you see any potential problems with managing the class of young people?
 - What does the site do to make each student feel important and at ease?
 - Where is the best location to project the PowerPoint slides?
 - How is the room arranged? Will you need to move desks or chairs for any part of your presentation?
 - How can you engage the site representative in your presentation?
- Meet with and finalize the logistics with the Site Representative?
 - Confirm the date, time, and location of the activity?
 - Confirm the technology needs? *Do you need to bring a computer and a projector to show the PowerPoint? Or, does the site have one that you can borrow?*
 - Confirm the number of students attending? *Knowing this will help you decide how to separate the class into teams and/or pairs, as well as the appropriate materials to purchase.*
- Recruit additional volunteers, if needed?
- Prepare for the activity:
 - Read the entire activity prior to implementation?
 - Customize the activity and tailor the PowerPoint, if desired, to reflect your background and experiences, as well as the cultural norms and language of the students in your community?
 - Preview the suggested video(s) and make sure it is appropriate for the students who will participate in the activity?
 - Complete the **Tell My Story Form**, which will prepare you to talk about your educational and career path with the students? If desired, include key points about your story on the PowerPoint (see **Tell My Story Slide**).
 - Determine how you will assign the teams? Students will be working in teams of four students. It is recommended that you randomly assign students to each team; this will foster the skills needed to work with new people.

- Obtain the required materials (see the **Materials** and **Estimated Materials Costs** section) and photocopy the **Student Handouts**? In addition:
 - Determine if you are interested in extending the student learning beyond the basic activity, consider reviewing the extended learning opportunities as well as the references and resources provided.
- Practice your presentation, including the hands-on, minds-on activity? Be sure to:
 - Review the content introduced in this activity. Key Words and background information are provided to assist you with implementation.
 - Be prepared to explain the engineering design process including the steps (component ideas) involved.
- Set up the site appropriately for the activity? Specifically:
 - Make sure tables and chairs are arranged to accommodate teams of students—four students per team.
 - If additional volunteers are available, assign one adult to work with two or three teams.
 - Set up the computer and projector for the PowerPoint presentation; be sure that speakers and an Internet connection are available.
 - Bring a camera, if desired, to take photographs.
- Obtain and collect permission slips and photo release forms for conducting the activity if applicable?
- Have fun!**



Tell My Story Form

This form will help volunteers serving as activity leaders prepare to talk about their **STEM²D** interests, education, and career path.

ABOUT YOU

Name: _____

Job Title: _____

Company: _____

When/Why did you become interested in STEM²D? _____

What do you hope young people will get out of this activity? _____

FUN FACT

Share a little about your background. Ideas:

- Share a memory from childhood where you first had your spark or interest in STEM.
- Detail your journey; highlight what you have tried, what you learned, steps to success, etc.
- Failures or set backs are also great to talk about—difficulties, and/or challenges and how you overcame them.

EDUCATION AND CAREER PATH

What classes/courses did you take in secondary school and in college that helped or interested you most?

How did you know you wanted to pursue a STEM²D career?

What was your postsecondary path, including the institution you attended and your degree? *If you switched disciplines, make sure you explain why to the students.*

What your current position entails. *Be sure to include how you use STEM²D on a typical work day.*

CHANGE IT, CREATE IT, SOLVE IT, ENGINEER IT

Student Handouts

All of these innovations have at least one thing in common.



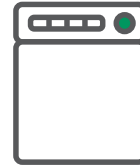
Car heater



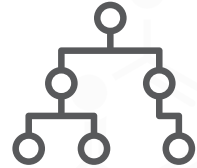
Circular Saw



COBOL computer language



Dishwasher



First computer algorithm



Kevlar



Syringe



Paper bag



Windshield Wipers

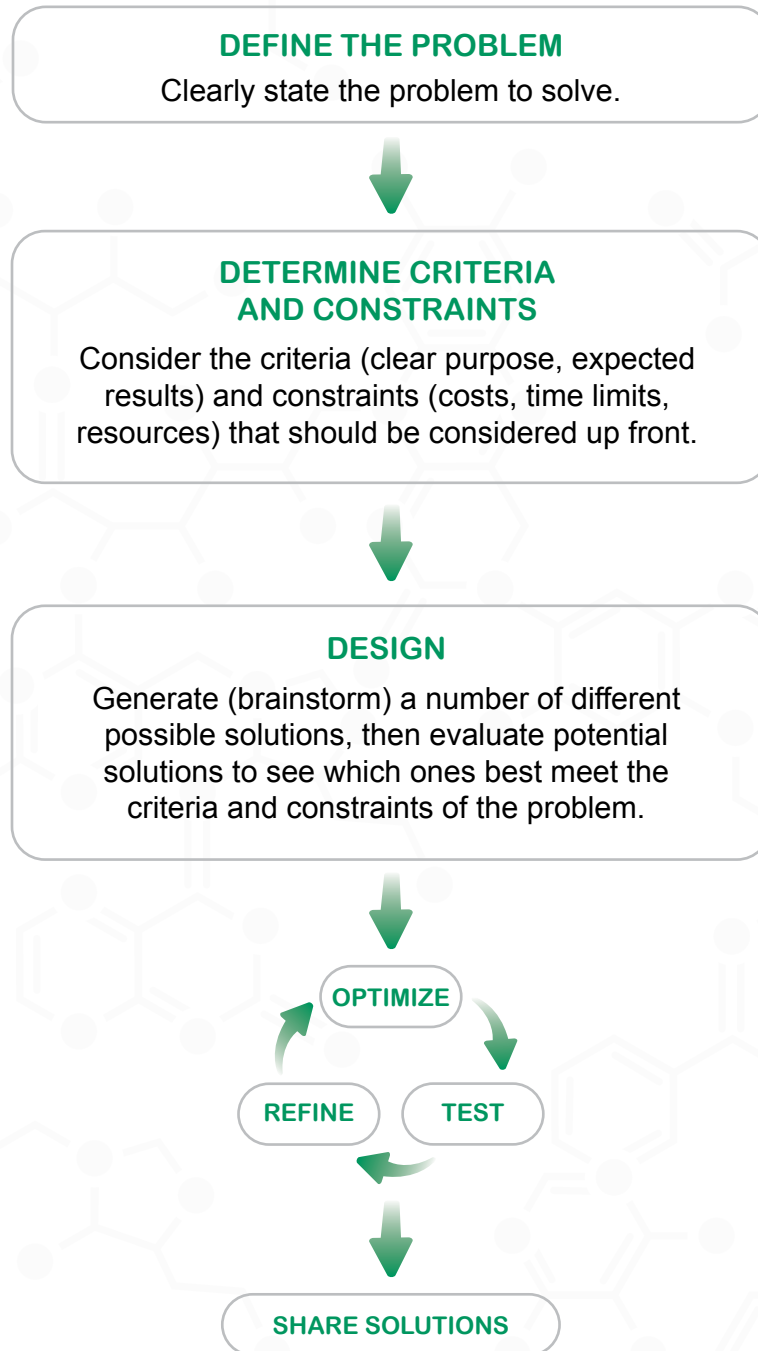


Wireless transmission technology

What is it?

Use this space to capture your ideas and thoughts about the innovations. Share and discuss your thoughts with someone sitting close to you.

Engineering Design Process



Something to consider: An engineer's initial ideas rarely solve the problem. Engineers must try different ideas, learn from her or his mistakes, and then try again.

Important! The component ideas do not always follow in order. Problem-solvers can redefine the problem or generate new solutions when ideas just are not working out.

Designing Solutions

Things to consider:

When you brainstorm think about:

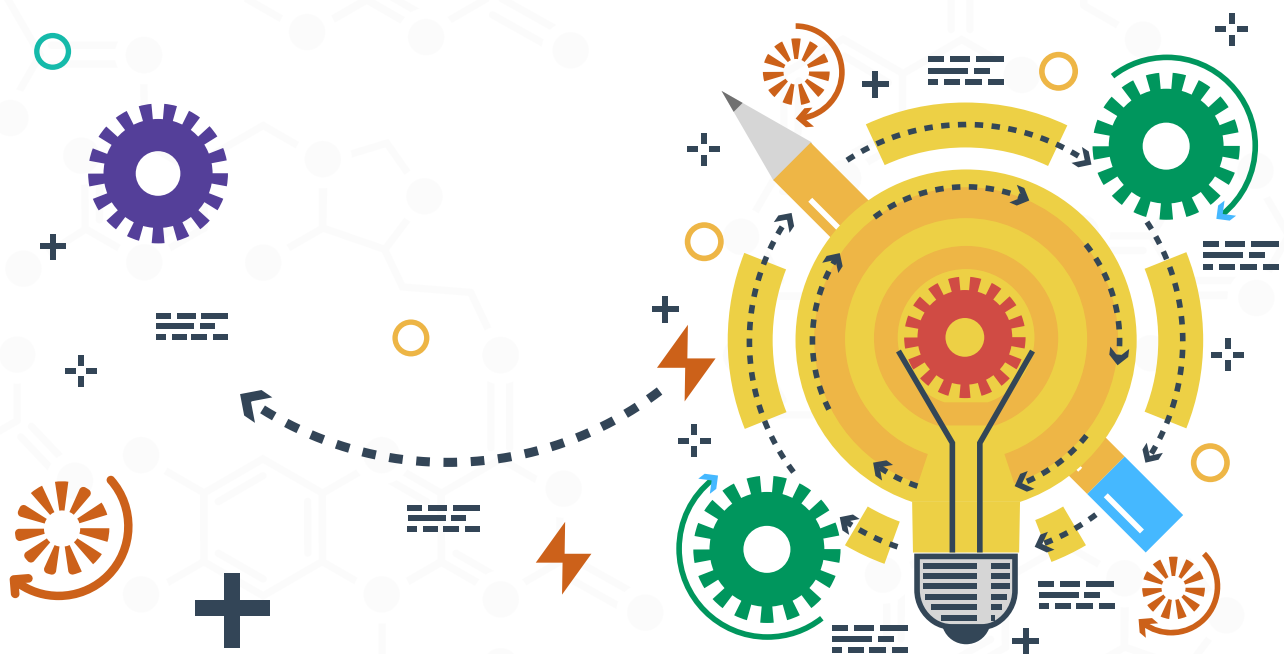
- What are different ways to tackle this problem?
- What are ways to be more creative?
- Off-the-wall suggestions often spark amazing ideas.

When you evaluate think about:

- Which ideas are really possible, given your identified constraints?
- What are some problems you need to solve as you build your solution?
- How can a sketch help clarify your design?

More things to consider when sharing your solutions:

- What is the best feature of the design? Why?
- What were the steps it took to get the design to work?
- What was the hardest problem to solve?
- Did we do anything more than once? If so, what?
- If we had more time, how would we improve our design?



Try It: Paper Airplanes



1. **Define the problem.** Design a paper airplane that travels the longest distance
2. **Determine criteria and constraints.** Resources are limited to one airplane per piece of paper, and no more than five pieces of paper per team. Teams have 10 minutes to prototype different options before submitting one design to fly in the team competition.
3. **Design.** Teams will brainstorm multiple designs that best use their limited resources to learn which design flies the farthest.
4. **Share solutions.** Discuss which versions worked best and why.

Another Try It: Learning Game Concept

You and your team will have 15 minutes to create a game concept. Teams need to define the problem, determine the criteria and constraints, design a solution, and be prepared to share it with the other teams. Your board (or card) game needs to teach young children how to investigate the world around them and practice one of the following science and math skills:

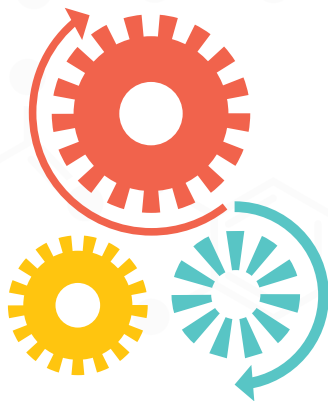
- Identify plants and animals
- Identify solids, liquids, and gases
- Add and subtract money amounts
- Multiply numbers

Directions

Complete the steps below and sketch your design in the space provided.

Define the problem.

Determine criteria and constraints. Consider the criteria (clear purpose, expected results) and constraints (costs, time limits, resources) that should be decided up front.



Design possible solutions. Generate (brainstorm) a number of different possible solutions, then evaluate potential solutions to see which ones best meet the criteria and constraints of the problem.

Create a sketch to clarify the team's design.

Identify possible materials needed to build the solution:

Conduct user testing. Ask another team what they like about your concept. What would they change? How will you use this information to redesign your game concept?

The background of the page is a solid teal color with a repeating pattern of white chemical structures. These structures include various organic molecules such as alkanes, alkenes, aldehydes, and aromatic rings, arranged in a dense, overlapping manner.

Content courtesy of Johnson & Johnson, FHI360, JA Worldwide,
and Smithsonian Science Education Center.

Design by JA Worldwide.

Support of this work made possible by Johnson & Johnson.

Revised design, JA Worldwide, April 2018