

BUILDING A PROSTHETIC ARM

STEM²D Topics:
Manufacturing and Design

Target Population:
Students, ages 9-13



Building a Prosthetic Arm is part of the **STEM²D Student Activities Series**. Developed by FHI 360 for Johnson & Johnson's WiSTEM²D initiative (**W**inning in **S**cience, **T**echnology, **E**ngineering, **M**ath, **M**anufacturing, and **D**esign), the series includes many interactive and fun, hands-on activities for youth.

BUILDING A Prosthetic Arm

STEM²D Topics: Design, Manufacturing
Target Population: Students, ages 12–18

ACTIVITY DESCRIPTION

In this team-based, hands-on activity, students will design, build, and test a prosthetic arm that meets a customer's needs.

ESTIMATED TIME



This activity typically takes **180 minutes** to complete and should be conducted in one session.

STUDENT DISCOVERIES

Students will:

- Explore design and manufacturing concepts.
- Participate in a team-based learning experience.
- Build important STEM²D—Science, Technology, Engineering, Math, Manufacturing, and Design—skills, such as collaboration, creative thinking, decision making, and problem solving.
- Realize that STEM²D offers diverse and exciting career opportunities.
- Have fun experiencing STEM²D.

GETTING READY

Materials

- Pre-Activity Leader Checklist
- Tell My Story Form
- Computer with projector, speakers, and Internet access
- Video: Manufacturing Contact Lenses (Johnson & Johnson)
<https://www.youtube.com/watch?v=0qRXyCQHkoM>
- Video: Inside Ford's Moving Assembly Line (Ford Motor Company)
https://www.youtube.com/watch?v=jLud5XYfY_c



STEM²D Skills

- Collaboration
- Communication
- Critical Thinking
- Decision Making
- Problem Solving
- Teamwork
- Testing



IMPORTANT NOTE!

In many locations, box cutters are not allowed to be brought on school property. Be sure to check with the school prior to gathering the materials. Consider using alternate materials (such as heavy-duty scissors) or having volunteers cut the cardboard per student direction. If using box cutters, review safety procedures and supervise usage. Several safety training videos are available. Try: https://www.youtube.com/watch?v=uD7gX-_Q2IQ



- PowerPoint: Building a Prosthetic Arm
- Student Handout: Building a Prosthetic Arm Challenge, *1 per student*
- Student Handout: Bill of Materials (BOM) Form, *2 per team*
- Student Handout: Criteria for Acceptance of Design, *1 per team*
- 3, 16 oz. water bottles, filled with the following amounts of water: empty, $\frac{1}{2}$ full, and full
- Prosthetic Arm Kit, *1 set of the following items per team of five students:*
 - 1 box cutter
 - 1 glue gun
 - 2 glue sticks
 - 1 pair of scissors
 - 1 pencil
 - 1 piece of cardboard (minimum 3 ft. x 2 ft. and thin enough for students to cut with box cutters)
 - 1 piece of string (3 ft. long)
 - 1 piece of Velcro (1 ft. long)
 - 1 ruler
 - 1 sharpie marker
 - 1 sheet of stickers for decoration, *optional*
 - 2 straws
 - 1 wooden skewer
 - 1, 16 oz. water bottle
- Additional materials that can be “purchased” by teams.
 - 5 box cutters
 - 5 glue guns
 - 20 glue sticks
 - 5 pairs of scissors
 - 15 pencils
 - 15 pieces of string (each 3 ft. long)
 - 15 pieces of Velcro (each 1 ft. long)
 - 5 rulers
 - 5 sharpie markers
 - 15 sheets of stickers for decoration, *optional*
 - 40 straws
 - 45 wooden skewers

Estimated Materials Cost:

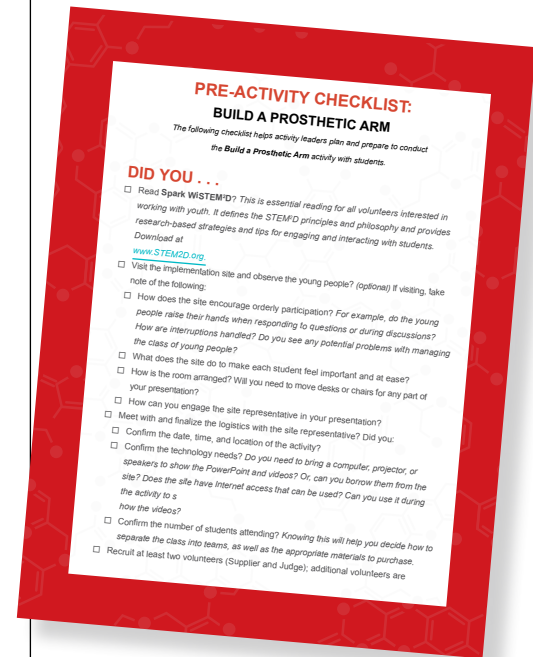
Activity leaders can expect to incur less than \$60 (excluding optional items) in materials costs when completing this activity with 20 students organized into teams of five students.

Activity Leader Preparation

1. Read **Spark WiSTEM²D**. This is essential reading for all volunteers interested in working with youth. It defines the STEM²D principles and philosophy and provides research-based strategies and tips for engaging and interacting with students. Download at www.STEM2D.org.
2. See the **STEM²D Student Activities Overview** for additional information.
3. Review the **Pre-Activity Leader Checklist** (at the end of this document) for details and specific steps for planning, preparing, and implementing this activity.

STEP-BY-STEP INSTRUCTIONS: CLEANSER CHALLENGE

1. **Welcome and Introductions (5 minutes)**
 - Welcome the students.
 - Introduce yourself by saying your name, title, and your organization/company.
 - Share that students will be learning about STEM²D careers and will be applying STEM²D skills during the session.
 - **(What is STEM²D? Slide)** Explain that **STEM²D** refers to: Science, Technology, Engineering, Math, Manufacturing, and Design.
 - Ask students and other volunteers to introduce themselves and state their favorite areas of STEM²D.
 - **(Today's Plan Slide)** Review the agenda. Explain that today students will design, build, and test a prosthetic arm that meets a customer's needs. Define **prosthetic**: an artificial body part.
2. **Career Awareness: STEM²D in the World of Work (10 minutes)**
 - **(Tell My Story Slide)** 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:



KEY WORDS

- Aesthetically
- Bill of Materials (BOM)
- Criteria
- Manufacturing
- Profit
- Profitable
- Prosthetic
- Prototype
- Quality Assurance

TIPS FOR STARTING CONVERSATIONS

- What area of STEM²D is your favorite?
- Why did you choose that area of STEM²D as your favorite?
- What would your dream job be?
- Where do you see yourself in 5–10 years?

TIPS ABOUT STEM²D CAREERS

Share with students that there are many different kinds of careers related to STEM²D.

Possible STEM²D careers related to this activity are:

- Automotive Designer
- Biomedical Engineer
- Design Engineer
- Quality Engineer
- Manufacturing Engineer
- Test Engineer

- When/why you developed an interest in design or manufacturing.
- The classes/courses you took in secondary school.
- Your post-secondary 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 design and manufacturing and what you do on a typical work day.*
- Weave in facts about design and manufacturing and STEM²D careers:
 - Tell the students that your career is only one of the many careers available in the STEM²D disciplines.
 - Explain that STEM²D careers are high-demand, high-growth careers and are predicted to remain in demand over the next ten years.
 - Share a few Johnson & Johnson job titles and careers that may align with this activity.
- **(STEM²D in the World of Work Slide)** Initiate an opening discussion and brainstorming activity. Ask students to raise their hands and share what they know about design and manufacturing. Consider asking:
 - What do you know about design and manufacturing?
 - What kinds of careers do you think people with an interest, aptitude for, or degree in design or manufacturing would have?
 - How do you think design and manufacturing are used every day in the workplace?
- Choose 3–4 students to share an answer (e.g., some products are manufactured on assembly lines; before products can be manufactured, they go through a design process; computers are frequently used in the design process; Johnson & Johnson, Procter and Gamble Company, 3M, Ford Motor Company, and Boeing are a few manufacturers).
- Provide feedback on student answers (e.g., if a student names a product that is manufactured, you may comment on how the item is manufactured or ask what materials may be used in the manufacturing process).

3. Content Presentation (15 minutes)

- **(Design Process Slide)** Give students an overview of the design process. Explain that there are many different design processes; in today's activity will use a seven-step process to design a new medical device:
 1. *Define the Need:* Determine the problem or challenge that needs to be solved.
 2. *Brainstorm:* Think about different ways to tackle the challenge. Share different ideas. Record all potential ideas for further discussion.
 3. *Design:* During this phase, teams collaborate and determine the ideas that have the most potential given the available time, tools, and materials. Explore these ideas in further detail. Create sketches of ideas. Determine materials to be used. Create working drawings so the selected idea can be built.
 4. *Build:* Make a model or prototype of the proposed design using the available materials.
 5. *Test and Evaluate:* Test the model in a controlled work environment to see if it produces the desired outcome. Gather data on the performance of the model. Check the results to determine if the model solved the problem. Identify areas of concern and shortcomings. Determine any changes to be made.
 6. *Rebuild:* Perfect the working prototype. Make any necessary changes to the design, based on testing and evaluation.
 7. *Share the Solution:* Answer the following questions: What is the best feature of the design? What different steps were taken to get the product to work? What modifications were made? Should this prototype be recommended for "market testing" and manufacturing?
- **(Manufacturing Slide)** Explain: **Manufacturing** is creating something from raw materials, either by hand or by machine. Indicate that as part of today's challenge, we will manufacture a medical device using the seven-step design process.

TIPS FOR MAKING CONNECTIONS

Encourage students to:

- Ask questions if they don't understand.
- Summarize what they have learned.
- Explain their thinking process aloud.

- Click the link(s) in the PowerPoint to watch one (or both) of the videos. *The Johnson & Johnson video is four minutes long. The Ford Motor Company video is two minutes long.*
- **(Questions? Slide)** Ask the students if they have any questions about design or manufacturing before moving on to the challenge. Answer questions posed by the students.

4. Learning Activity: The Prosthetic Arm Challenge (100 minutes)

Take approximately 20 minutes to explain the learning activity, leaving teams 80 minutes to design, build, and test their prosthetic arm.

- Break the large group into teams of five students per team. If a team does not have five members, someone in the team will need to play two roles.
- Instruct students to join their teams and sit together for the remainder of the session.
- Distribute the handouts. Encourage students to review the Build a Prosthetic Arm Challenge handout, as you outline the tasks of the challenge.
- **(Prosthetic Arm Challenge Slide)** Explain:
 - Your challenge is to design and build a prosthetic arm that fulfills a customer's needs.
 - Your **prototype** (model) must be able to pick up a 16 oz. water bottle that is empty, $\frac{1}{2}$ full, and full.
 - The prototype must be **profitable**. Define **profitable**: A business or activity yielding financial gain or a profit. Define **profit**: the difference between the amount earned and the amount spent in buying, operating, or producing something). The prototype should cost less than \$60.
 - Use only supplies provided or purchased.
 - Teams have 80 minutes to complete the challenge.
- **(The Customer's Needs Slide)** Explain that a customer has expressed the following needs for his/her prosthetic arm:
 - I want it to be lightweight.
 - I want it to be stable.
 - I want it to be able to grasp things of different weights.
 - I want it to be cost efficient.
 - I want it to be aesthetically pleasing or colorful/cheerful. (Define aesthetic: attractive or beautiful.)

- I want it to work and look better than the one I currently have.
- I want it to be comfortable.
- **(Prosthetic Arm Kit Slide)** Distribute a Prosthetic Arm Kit to each team. Indicate that the supply kit costs \$50 and contains a variety of supplies that can be used to design and build a new prosthetic arm, including a box cutter, glue gun and glue sticks, scissors, a pencil, a piece of cardboard, string, Velcro, a ruler, a sharpie marker, stickers, straws, and a wooden skewer.
- **(Additional Supplies Slide)** Introduce the Supplier (the volunteer selected to distribute the additional supplies). Indicate that teams can purchase additional materials, as needed from the supplier. The costs of the additional supplies are as follows:
 - box cutter = \$5
 - glue gun = \$10
 - glue stick = \$3
 - pair of scissors = \$3
 - pencil = \$1
 - piece of string (3 feet long) = \$1
 - piece of Velcro (1 foot long) = \$5
 - ruler = \$1
 - sharpie marker = \$1
 - sheet of stickers = \$1
 - straw = \$1
 - wooden skewer = \$1
- **(Team Roles and Responsibilities Slide)** Indicate that each team member will have a specific role and responsibilities in creating the prototype. Roles and the main responsibilities are:
 - *Marketing*: Ensures the team's prototype meets the needs and priorities of the customer.
 - *Research and Development (R&D)*: Leads the team in the development of the prototype.
 - *Operations*: Buys the materials required by R&D and informs finance of all items purchased. Leads the team in building the prototype.
 - *Finance*: Records all materials purchased on the **Bill of Materials (BOM)**. Confirms that the design is within budget and that the product is profitable.

TIPS FOR ENGAGING STUDENTS

- Ask open-ended questions to encourage student reflection and discussion. For example:
 - How did you decide what materials to use?
 - What factors determined the design of your prosthetic arm?
 - What is most challenging about building the prosthetic arm?
- Help students stay on track with time during the group challenge.
- Encourage all students to participate in the challenge.
- Move around the learning space and provide support when necessary.
- *Quality*: Reviews the final product for **quality assurance**. Ensures that all parts used match the BOM. (Define quality assurance: The maintenance of a desired level of quality in a service or product, especially by means of attention to every stage of the process of delivery or production.)
- **(Pre-Work Slide)** Instruct teams that prior to starting the challenge, they must first complete three “pre-work” activities:
 - Choose a team name.
 - Assign each team member a role.
 - Complete initial role-specific tasks:
 - *Marketing*: Review the customer’s needs and priorities; be ready to share these with the team.
 - *R&D*: Review the contents in the supply kit. Think about how the materials could potentially be used in the prosthetic arm prototype. Start a list of potential additional items that may be required.
 - *Operations*: Organize the supplies and work with the Quality team member.
 - *Finance*: Review the Bill of Materials handout; be sure you know how to calculate the total expenses and determine if prototype is profitable.
 - *Quality*: Talk with the Operations team member and come to an agreement on criteria for accepting the design. The criteria (rules or principles for evaluating or testing something) should be documented on the Criteria for Acceptance handout.
- The pre-work should take no more than 10 minutes.
- **(Design Your Prototype Slide)** State that once the pre-work is done, the team should design its prototype. This phase should take approximately 20 minutes. Stress that while different team members lead each step in the design phase, all team members must participate. Review the tasks of the design phase, as outlined on the handout:
 - *Define the need*: Review the needs of the customer; prioritize the needs. (Lead: Marketing)
 - *Brainstorm*: Share ideas and discuss potential solutions to help meet the top prioritized needs. (Lead: R&D)
 - *Design*: Sketch potential designs and agree on a design for the prototype. (Lead: R&D)

- *Design*: Determine the materials to be used. (Lead: Operations)
- *Record*: Complete the BOM and confirm if the prototype is within budget; if necessary, draft a new BOM, eliminating lower priority parts. (Lead: Finance)
- **(Manufacture Your Design Slide)** Indicate that once the design phase is complete, teams should spend about 30 minutes manufacturing (building) and testing the prototype. Review the tasks of the manufacturing phase, as outlined on the handout:
 - *Build*: Make a model or prototype of the proposed design using the available materials. (Lead: Operations) Remind students to be careful when using the glue gun and box cutters; if they need help, they should ask a volunteer for assistance.
 - *Test*: Test the model in a controlled work environment to see if it produces the desired outcome. Gather data on the performance of the model. Check the results to determine if the model solved the problem. Identify areas of concern and shortcomings. (Lead: Quality) Indicate that each team has a water bottle that should be used to its product. Teams should fill the bottle to the three designated amounts (empty, ½ full, full) when testing. The final design should be able to withstand the weight of a full water bottle.
 - *Evaluate*: Determine any changes to be made. (Lead: R&D)
 - *Rebuild*: Perfect the working prototype. Make any necessary changes to the design, based on testing and evaluation. (Lead: Operations)
 - *Share the Solution*: As a team, answer the following questions: What is the best feature of the design? What different steps were taken to get the product to work? What modifications were made? Should this prototype be recommended for “market testing” and manufacturing? (Lead: Marketing):
- **(Finalize Your Product Slide)** Explain: Teams should finalize their prototypes by completing the following tasks:
 - Create a final BOM and have all team members sign it. (Lead: Finance)

- Take the final BOM to the Supplier and return any supplies not listed on the BOM. (Lead: Operations)
 - Review, to make sure the parts used match the BOM and all the acceptance criteria are met (Lead: Quality)
 - Deliver the prosthetic arm to the judge. (Lead: Quality)
 - **(Questions? Slide)** Ask the students if they have any questions about the challenge and the process you have described before getting started. Answer questions posed by the students.
 - **(Get Started! Slide)** Remind teams they have 80 minutes to design, build, and test their designs. Circulate the room, asking students questions about their designs. Although you may be tempted to give suggestions for improvement, hold onto these until the reflection period so teams have the opportunity to work through the product design process.
- 5. Performance Testing (30 minutes)** After 80 minutes, reconvene the large group. Indicate that it is time to test each device.
- Introduce the Judge (the volunteer assigned to oversee performance testing).
 - Instruct the Quality team members to deliver their prototypes and BOM forms to the Judge.
 - **(Performance Testing Slide)** Place the three bottles (empty, ½ full, full) on a table at the front of the room (order from least filled to most filled).
 - Choose a team at random to undergo performance testing. Have the Judge verify the team's BOM form against the items used to build the prototype. If the form is incorrect, the Judge identifies what is incorrect and the team either corrects the form or removes the item from the device.
 - Ask the team's Marketing and Finance members to describe the design and present the final cost of the materials. Have the R&D team member showcase the functionality of the prosthetic arm by lifting an empty water bottle, followed by ½ full and full water bottles. If the device breaks or the bottle is too heavy for the device to lift, the testing stops at that point.
 - Record the team's level of success on the chalkboard/whiteboard (e.g., Team 1: full bottle, Team 2: empty bottle, Team 3: ½ full bottle, etc.)
 - Repeat the process, randomly selecting teams for performance testing and recording the levels of success.

- Once all the devices have been tested, circle on the board the team(s) with the device(s) that lifted the most water.
- Announce the device(s) that were successful lifting water bottles with the most amount of water (e.g., Team 1's device lifted a full bottle of water). If two teams successfully lifted the same amount of water, determine the winner by reviewing each team's profit (e.g. Team 1's device cost \$60, but Team 2's device cost \$62).
- Remind students that products are often redesigned or rebuilt after going through the Test and Evaluate phases of the design process.
- **(What Did We Learn? Slide)** Have students recap the lessons learned during the activity by asking one or more of the following questions:
 - What was the most critical decision your team made during the Design Your Prototype Phase?
 - What did you learn about working in a team?
 - What was the most critical decision your team made during the Manufacture Your Design Phase?
 - What was the most critical decision your team made during the Finalizing Your Product Phase?
 - What was difficult about designing and building your prosthetic arm?
 - What would you change about your design if you were to do it again?

6. Student Reflection (20 minutes)

- **(Reflection Slide)** Ask students to reflect on the activity. Pose one or more of the following questions:
 - What did you learn about Design and Manufacturing?
 - How do you think this activity relates to a career in Design and Manufacturing and/or working at Johnson & Johnson?
 - Can you see yourself as a STEM2D professional? In what role? Why or why not?
 - What would you need to do to make that happen?
 - What is one thing you learned that you did not know when you came here today?

Extended Learning

You can extend student learning by:

- **Create It, Try It, Manufacture It.** Go to: <https://www.stem2d.org/activities/#makeit>
- **Cotton Ball Catapult.** <https://www.stem2d.org/activities/#catapult>

Key Words

- **Aesthetic:** a pleasing appearance or effect.
- **Bill of Materials (BOM):** a comprehensive list of parts, items, assemblies and other materials required to create a product.
- **Criteria:** rules or principles for evaluating or testing something.
- **Manufacturing:** creating something from raw materials, either by hand or by machine.
- **Profit:** the difference between the amount earned and the amount spent in buying, operating, or producing something.
- **Profitable:** a business or activity that yields a profit or financial gain.
- **Prosthetic:** an artificial body part.
- **Prototype:** a simple model that lets you test your idea.
- **Quality Assurance:** the maintenance of a desired level of quality in a service or product, especially by means of attention to every stage of the process of delivery or production.

Resources and References

Special thanks to Joseph Lao, Product Quality Engineer, ASP and BTE–Santa Ana, California, Champion for his guidance and insights on this activity.

The following references and resources provide additional information or activities:

- Automation, Innovation, and Business – STEM for Kids
<https://stemforkids.net/programs/advanced-manufacturing/>
- Tackle the Engineering Design Process – with Kids!
<https://stemactivitiesforkids.com/2016/02/25/690/>
- Video: The Engineering Design Process – A Taco Party
https://www.youtube.com/watch?v=MAhpfFt_mWM
- Video: Kid Engineer – The Design Process Design Squad
<https://www.youtube.com/watch?v=FuzmxrqqBLc>

PRE-ACTIVITY CHECKLIST:

BUILDING A PROSTHETIC ARM

*The following checklist helps activity leaders plan and prepare to conduct the **Building a Prosthetic Arm** activity with students.*

DID YOU . . .

- Read Spark WiSTEM2D? This is essential reading for all volunteers interested in working with youth. It defines the STEM2D principles and philosophy and provides research-based strategies and tips for engaging and interacting with students. Download at www.STEM2D.org.
- Visit the implementation site and observe the young people? (optional) If visiting, 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?
 - 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? Did you:
 - Confirm the date, time, and location of the activity?
 - Confirm the technology needs? *Do you need to bring a computer, projector, or speakers to show the PowerPoint and videos? Or, can you borrow them from the site? Does the site have Internet access that can be used? Can you use it during the activity to show the videos?*
 - Confirm the number of students attending? *Knowing this will help you decide how to separate the class into teams, as well as the appropriate materials to purchase.*
- Recruit at least two volunteers (Supplier and Judge); additional volunteers are encouraged and can serve as additional judges or be assigned to specific teams for additional support and guidance.

- Prepare for the activity:
 - Read the entire activity text prior to implementation?
 - Review the key content to be shared?
 - Watch the recommended videos. Determine the video(s) to be included in the presentation.
 - 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? Review the notes section of the slides in the PowerPoint for information to be shared?
 - 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.*
- Obtain the required materials. *See the Materials and Estimated Materials Costs sections .*
- Practice your presentation, including the hands-on, minds-on activity? Be sure to:
 - Do the activity! *Make sure you are able to explain the concepts to students, if needed, and that you know the correct answers.*
- Set up the site appropriately for the activity? Did you:
 - Make sure tables and chairs are arranged to accommodate teams of five students? *If more than two volunteers (Supplier and Judge) are available, assign volunteers to specific teams.*
 - Set up the computer and projector for the PowerPoint presentation? Connect the speakers? Make sure the Internet connection is available to show the videos?
- 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 activity leaders and other volunteers 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 when you had your first 'spark' or 'interest' in STEM²D.
- Detail your journey—highlight what you've tried, what you learned, steps to success, etc.
- Failures or set backs are also great for talking 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 during a typical work day.* _____

BUILD A PROSTHETIC ARM CHALLENGE

Student Handout

CHALLENGE

Work as a team to design, build, and test a prosthetic arm that meets a customer's needs. The prototype must cost less than \$60 to make and be able to pick up a 16 oz. water bottle (an empty bottle, a ½ full bottle, and a full bottle).

TIME

80 minutes

OVERVIEW OF CUSTOMER NEEDS:

- ✓ Lightweight
- ✓ Stable
- ✓ Able to grasp things of different weights
- ✓ Cost efficient
- ✓ Aesthetically pleasing (colorful/cheerful)
- ✓ Works and looks better than the current prosthetic arm
- ✓ Comfortable

INSTRUCTIONS

1. **Pre-Work (10 minutes).** Before any designing and building, you must first accomplish the following pre-work:
 - Choose a name for your team.
 - Determine each team member's role:

Role	Responsibilities	Team Member
Marketing	Ensures that the team's prototype meets the customer's needs and priorities.	
R&D	Leads the team in the design of the prototype, including brainstorming.	
Operations	Buys the materials required by R&D and informs finance of all items purchased. Leads the team in building the prototype.	
Finance	Records all materials on the Bill of Materials (BOM). Confirms the design is within budget and that the product will be profitable.	
Quality	Reviews the prototype for quality assurance. Ensures that all parts used match the BOM.	

- Complete role-specific tasks:
 - **Marketing:** Review the customer's needs and priorities; be ready to share these with the team.
 - **R&D:** Review the contents in the supply kit. Think about how the materials could potentially be used in the prosthetic arm prototype. Start a list of potential additional items that may be required.
 - **Operations:** Organize the supplies and work with the Quality team member.
 - **Finance:** Review the Bill of Materials handout; be sure you know how to calculate the total expenses and determine if prototype is profitable.
 - **Quality:** Talk with the Operations team member and come to an agreement on criteria for accepting the design. The criteria (rules or principles for evaluating or testing something) should be documented on the Criteria for Acceptance handout.

2. Design the Prototype (20 minutes). As a team, complete the following steps:

- Prioritize the needs of your customer.
- Brainstorm potential solutions to help meet the top prioritized needs.
- Sketch potential designs and agree on a design for the prototype.
- Determine the items needed to best meet the customer needs.
- Have the Operations team member complete a draft BOM with the required items.
- Have the Finance team member confirm if the BOM is within budget.
- If necessary, the Operations team should draft a new BOM, eliminating lower priority parts.

3. Manufacture Your Design (30 minutes). Once you have agreed on a design and made a final determination of the materials to be used, complete the following tasks:

- **Build:** Make a model using materials that provide a solution to the problem.
- **Test & Evaluate:** Test the model in a controlled and working environment. Gather data on the performance. Check the results to determine if the model solved the problem. Identify areas of concern and shortcomings and determine any changes to be made. Each group has a water bottle that can be used to test the product. Fill the bottle to varying amounts when testing. Your final design should be able to withstand the weight of a full water bottle.
- **Rebuild:** Make any necessary changes to the design, based on testing and evaluation.
- Remember to track any changes in your use of supplies on your BOM!

4. Finalize Your Product (10 minutes). Once you have built and tested your design, complete the following tasks:

- **Build:** Create a final BOM and have all team members sign it. Take the final BOM to the Judge and return any materials not listed on the BOM to the Supplier.
- **Quality:** Review to make sure the parts used match the BOM and all the acceptance criteria are met. Once the acceptance criteria are met, deliver the prosthetic arm to the Judge.

5. Performance Testing. After 80 minutes, we will test the devices as a group and see which design works the best.

BILL OF MATERIALS FORM

Student Handout

Item	Cost (\$)	No. Used	Total Cost (\$)
Initial supply kit	\$50	1	\$50
Box cutter	\$5		
Glue gun	\$10		
Glue stick	\$3		
Pair of scissors	\$3		
Pencil	\$1		
Piece of string (3 feet long)	\$1		
Piece of Velcro (1 foot long)	\$5		
Ruler	\$1		
Sharpie marker	\$1		
Sheet of stickers	\$1		
Straw	\$1		
Wooden skewer	\$1		
		TOTAL COST	

Team Member Signatures:

CRITERIA FOR ACCEPTANCE OF DESIGN

Student Handout

INSTRUCTIONS:

The Operations team member should help the team come to an agreement on the criteria for accepting the design. The criteria (rules or principles for evaluating or testing something) should be documented below.

CRITERIA:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

The background of the entire page is a repeating pattern of various chemical structures, including benzene rings, aliphatic chains, and functional groups, rendered in a light red color against a darker red background.

Content and graphic design courtesy of FHI 360.

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