GET A GRIP!

Take the challenge! See if you can build a functional prosthetic arm from low-cost, readily available materials like plastic pipe, wood shims, hooks, and duct tape.

Get a Grip! was designed as a biomedical engineering–themed informal science curriculum for middle school youth.

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This unit was adapted from a science curriculum unit developed under the leadership of Suzanne Olds as part of the VaNTH Engineering Research Center for Bioengineering Educational Technologies, funded by the National Science Foundation.

Learn more about the Science Club initiative at scienceclub.northwestern.edu.
About Science Club

Science Club is an afterschool science program developed by the Center for Genetic Medicine at Northwestern University and the Robert R. McCormick Boys & Girls Club in Chicago, Illinois.

It utilizes a mentor-based approach to provide fun, inquiry-based activities for middle school youth. On a weekly basis throughout the academic year, Northwestern science graduate students and staff travel to the McCormick Club to serve as youth mentors, guiding them through the initiative’s curriculum. Field trips and social activities also promote mentor-youth relationship development.

At the conclusion of each quarter, Science Club members have the opportunity to share the results of their inquiry with fellow students, Boys & Girls Club members, and parents.

Disclaimer
The information contained in this activity is intended as an instructional resource for informal science educators. It should in no way be construed as medical advice, opinion, diagnosis, or treatment. All activities in this guide should be closely supervised by knowledgeable adults, and all standard safety practices followed. Northwestern University and/or the National Institutes of Health (NIH) cannot be held responsible for any injury or accident that may result from the activities in this guide.

Acknowledgements
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**Overview**

**About Get a Grip!**

*Get a Grip!* is a project-based informal science education unit that challenges students to design and construct a prosthetic arm for a fictional Afghan girl who has been injured in a landmine explosion.

The curriculum was designed for a mentor-led small-group setting (3–4 youth per mentor). Mentors should feel free to adapt the activities and challenges according to the abilities and interests of the group. These modules have been used successfully for youth in grades 5–8.

**Pedagogy**

The curriculum follows the Legacy Cycle framework derived from *How People Learn* (Bransford, Brown, and Cocking, 1999). The Legacy Cycle helps ensure that the unit incorporates the four “centerednesses” of the *How People Learn* theory:

- Knowledge-centeredness: Appropriate information is presented in a sequenced and organized way
- Student-centeredness: The lesson seeks out students’ prior conceptions and helps students connect with prior knowledge
- Assessment-centeredness: The learning experience provides students with opportunities to check their own understanding and provides mentors the opportunity to assess effectiveness of their teaching
- Community-centeredness: Students are provided with opportunities to learn collaboratively

All lessons in *Get a Grip!* allow students the opportunity to compile and discuss their current knowledge with warm-up questions and provide formative assessment through a concluding discussion.
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Introduction to Design Challenge
Students are introduced to Laila, a fictional 12-year-old Afghan girl injured by a landmine explosion, and challenged to design a prosthetic arm for her. To research the problem, students explore life in Afghanistan and compare it to their own experience living in Chicago. Additionally, students get to explore and compare the designs of modern prosthetic devices. (90 minutes)

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Disability Awareness
Students experience how amputation complicates activities in their daily lives and learn how tools help adapt these activities for people with disabilities. To further their understanding of adaptation and to begin the building process, students design and construct a small tool to help pick up a key ring. (90 minutes)

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Students learn about the engineering design process, a multistep method that allows for effective instrument design. Students practice the engineering design process while designing and building a tool to pick up candy. (90 minutes)

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Building a Prosthetic Arm
During this multiweek lesson, students build a prosthetic arm for Laila, testing its ability to carry a bucket of water and pick up olives. Students revise their designs based on their testing. At the end of Lesson 6, each group prepares for the final design competition. (three to four 90-minute sessions)

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Design Competition
In the Get a Grip! finale, each group of students will test their prosthetic arm in a competition against the other groups. The highest combined score for the two challenges – carrying a bucket of water and picking up olives – will determine the winner! (90-minutes)
My scientific question:
Good questions are scientifically testable. This means you can design an experiment to figure out the answer. Good, testable questions often start with “What is the effect of...?” or “Does [X] affect [Y]...?” If the answer to your question is a fact, or something you can easily find out on the internet, these are NOT good questions.

**Awesome!**

What is the effect of the amount of citric acid on the flavor of soda?

**Needs some work...**

Why does soda taste so good?

IDEA: Can you change any ingredients in pop and see if it’s still tasty?

What I did:
List ALL the important steps. Always use numbers to describe amounts and measurements. Good scientists change only one variable at a time. Good scientists also repeat their experiments more than once. This adds confidence to the results.

**Awesome!**

We used 3 cups of pineapple juice and 3 cups of water and experimented with different amounts of citric acid and sugar. In one trial we used 3/4 cup sugar and 1 tsp citric acid. In another trial we kept the sugar the same but added less citric acid (1/4 tsp). We made a 1-10 scale to rate the pop. 10 was perfect. We had 3 raters.

**Needs some work...**

We used some juice and water to make our soda. One time we changed the amount of juice we added, and we also added some sugar. Another time we we added more acid and juice, but didn’t add any sugar.

IDEA: Use numbers, change only one variable at a time, share how you rated taste, repeat your experiment.

What I found:
Summarize your results, using numbers. Compare your experimental data to your control data. If you repeated your experiments, calculate an average.

**Awesome!**

With 1 tsp of citric acid, the soda was much too tart, scoring an average of 3/10. But with only 1/4 tsp of citric acid, the soda scored an average of 8.5/10. It tasted much better.

**Needs some work...**

All of our sodas were very tasty.

IDEA: What did you use as your comparison pop? Did some taste better than others?
Draw or tape a picture of your experiment here.

My Scientific Question: _____________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
What I did: ________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
What I learned: ______________________________________________________________
_____________________________________________________________________________
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My Science Journal
A guide for instructors

Draw or tape a picture of your experiment here.

If cameras and printing are available, students can use photos to illustrate their journal post. If not, they can draw a diagram or sketch of the experiment.

My Scientific Question: □ Is the question experimental or testable?
□ Does it include the variables being tested?

Possible formats: “What is the effect of X on Y?” “How does X change Y?”

What I did: □ Does the journal post provide a brief description of the methods? Measurement techniques?
□ Does the post include information about control groups and variables?

What I learned: □ Does the post include quantitative data?
□ Does the post include comparisons between experimental groups?
□ Does the post use data to make a conclusion?
□ Does the post describe possible sources of error?
Prototype Design

If you run out of room, answer the question on a separate sheet of paper and attach it.

What is the problem?: ____________________________________________________________

How will you address the problem?: ________________________________________________

What are the requirements for your prototype?: ______________________________________

Brainstorm some ideas:

Which idea will you use in the prototype?: ________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________
Prototype Design

Describe or draw the prototype:

How will you build the prototype?
Test the Prototype

If you run out of room, answer the question on a separate sheet of paper and attach it.

My experimental question: ________________________________________________________

My hypothesis: _________________________________________________________________

What I will measure: _____________________________________________________________

How I will measure it: ____________________________________________________________

<table>
<thead>
<tr>
<th>Variable</th>
<th>Changes</th>
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What I am going to do: _____________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________
Test the Prototype

My Data:

Data Analysis:

My results: ____________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

My conclusion: ________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

My hypothesis was right wrong (circle one)

Why? ________________________________________________________________
____________________________________________________________________
____________________________________________________________________
Lesson 1: Introduction to the Design Challenge

Lesson Objectives

- Meet Laila, a young girl injured in Afghanistan
- Learn about life in Afghanistan and compare to life in Chicago
- Examine modern prosthetics

What You Need to Know

Laila is a fictional 12-year old girl living in Afghanistan. While playing soccer with her friends, Laila’s arm was injured by a landmine buried in the field. Doctors amputated Laila’s arm and now she needs a prosthesis to help her carry a bucket of water from the river and to help her eat olives, a common food in Afghanistan.

Over the next six weeks, your group will work together to design a trans-radial (below-the-elbow) prosthetic device for Laila using materials that are easily found in Afghanistan. The prosthesis must be durable, because Afghanistan is a rugged place, covered by rocky mountains and arid deserts. It also cannot cost too much, since the average Afghan family earns only $800 a year from their work on the farm or in raising livestock.

At the end of this unit, the prosthesis you build will compete against the designs from other groups in a design competition.

Materials

- Laptop computer or computer and LCD projector (for playing video)
- Photos of Afghanistan and Chicago (included in the Lesson 1 appendix, p. 7)
- Actual prosthetics or photos of prosthetics

Prep Work

- Watch Laila video before meeting with kids.
- Make copies of prosthetic images for each group.
- Print images of Afghanistan and Chicago with captions describing the details of the photos (see appendix, p. 7)
- Optional – laminate photos and hang them on the walls of the room. Hang Afghanistan and Chicago images side-by-side for comparison.

Prosthetic Limbs

A prosthesis is an artificial limb that replaces a missing arm or leg. There are many types of prostheses.

The Jaipur foot is readily available to impoverished nations and costs $35.

In contrast, prosthetics in the US cost $6,000–35,000+. Prostheses in the United States are made from materials such as plastic, metal (aluminum, steel, titanium), silicon, latex, and carbon fiber. These devices can also have robotic components.

Time

60–90 minutes (total)
Lesson 1: Introduction to the Design Challenge, continued

Warm-Up Questions
• Do you know where Afghanistan is located?
• What do you think life is like in Afghanistan?
• Do you know anyone with a prosthetic limb, or have you ever seen anyone using a prosthetic limb?

Procedure
1. Spend some time getting to know the kids in your group.
2. Find a quiet corner for your group to work. Introduce the goal for the unit — to work as a team to build a prosthetic limb.
3. Show the video about Laila and the design challenge. The video is available online at http://bit.ly/fI2Qbq
4. Start a discussion about life in Afghanistan. An example question: How is life in Afghanistan different from life in Chicago?
5. Spend some time examining the photographs of Afghanistan. Compare them to the photos of life in Chicago. You could also make a Venn Diagram, comparing and contrasting Chicago and Afghanistan.
6. After exploring life in Afghanistan, give the group an opportunity to discuss prosthetic limbs.

Example question: What do you know about prosthetic or artificial limbs?

7. Have the group examine actual prosthetic devices, or show images of prosthetics. Allow the kids to ask their own questions and make their own conclusions. It might help to ask questions like: What are these prosthetics made of? How do they move? What do you think it is like to wear one of these devices? This might also be a good time to ask the kids if they have any ideas for Laila’s prosthesis.

Concluding Discussion
• How might prosthetics in Afghanistan differ from ones in Chicago?

Prosthetics in Afghanistan are made from less expensive materials and must be more durable. In the US, artificial limbs are often made from expensive materials, can be electronically powered, and often require more maintenance.

• What kinds of activities will Laila have to perform with her prosthetic limb?

Laila will need to be able to carry water from the river, eat meals with her family, and play with her friends.

• If you had an amputated arm, what do you think would be the hardest activities to accomplish?

There are a lot of possible answers to this question. Some examples include taking a bath, getting dressed, writing or drawing, playing sports, and cooking and eating food.

Facts about Afghanistan

Afghanistan flag
credit: mapsofworld.com

Kabul is the capital of Afghanistan.

Afghanistan is slightly smaller than the state of Texas, measuring 251,825 square miles.

There are 31,056,997 people living in Afghanistan, much less than the 298,444,215 living in the US.

70% of Afghans work as farmers or raise livestock.

Only 4% of Afghan kids go to primary school.

Most families get their drinking water from a nearby river.
Lesson 1 Appendix: Photo Guide for Daily Life in Afghanistan and U.S.

Daily life in Afghanistan is quite different from the average American lifestyle. To learn more about the differences between our two cultures, let’s have a look at some photographs comparing life in Kabul, Afghanistan to life in Chicago, IL.

Instructions
Print out the images included in this appendix. You can either hang them side-by-side in the room, or keep them at your table for viewing. Mentors should invite their groups to view the photographs, inviting them to compare and contrast the details in each image. Similarities and differences should be noted, and will be important information to use in the design challenge.
Chicago, IL, United States

Lawrence Ave

credit: Google Maps
Can you find Chicago, IL and Kabul, Afghanistan?

credit: http://apod.nasa.gov/apod/ap020810.html
Chicago, IL

credit: http://apod.nasa.gov/apod/ap020810.html
Houses on a hillside near Kabul, Afghanistan
Apartments in Chicago, IL
Afghan men playing the national sport, buzkashi ("goat grabbing")

credit: www.317am.net
Chicago loves sports, including football, basketball, and baseball
Boys going to school in Afghanistan

credit: thehumanitarianspace.com
Boys and girls at school in Chicago, IL
Afghan girls collecting water from a well

credit: faculty.college-prep.org
Getting water from the kitchen sink
Afghanis shopping at the neighborhood marketplace

credit: en.wikipedia.org
People shopping at an American grocery store

credit: departmentstorescrets.blogspot.com
Outdoor kitchen found outside an Afghani home
Kitchen inside a Chicago, IL apartment

credit: Rebecca Daugherty
An Afghan family sitting down to eat dinner
An American family cooking dinner

credit: happyfamilies.blogspot.com
People eat with their hands in Afghanistan
Americans often use utensils to eat their food
Lesson 2: Disability Awareness

Lesson Objectives

- Students will learn how amputation complicates everyday during some disability awareness activities
- Building challenge: Design a tool to pick up a key ring

Refresher

In the last lesson, the students met Laila, a 12-year-old Afghan girl living with an amputation, and your group was challenged to build a prosthetic arm for her. To begin researching this problem, everyone learned about life in Afghanistan and saw some examples of prosthetics.

What You Need to Know

There are approximately 1.9 million people living in the US without the use of one of their limbs. Amputation is also quite common in Afghanistan as a result of injury from one of the many forgotten landmines left over from war.

In this lesson, students will perform tasks without the use of one of their hands. Most people use their dominant hand to do things such as reach for an object. Therefore, it is the dominant hand that is most often injured by landmines or other trauma. Students should try these tasks without the use of their dominant hand.

Students will also learn about how tools help amputees accomplish everyday activities for amputees as they construct a device for picking up a key ring.

By the end of this lesson, students will be able to empathize with amputees and consider some possible features for their prosthetic designs.

Materials

- Materials for disability awareness tasks, such as Jolly Ranchers and bags of chips
- Latex gloves
- Masking tape
- Assorted tools such as tongs, plastic silverware, screwdriver, hammer, and tweezers
- Materials for building challenge: possibilities include steel band clamp, wood dowel, electrical tape, masking tape, cable tie, wire hanger, plastic bottle, paper clips, L-shaped metal brace
- Paper and pencils for drawing

Prep Work

- Assemble materials and tools for the disability awareness activity. Make one box of materials per table.
- Print one disability awareness worksheet for each student. Distribute worksheets and pencils.
- Collect materials for the building challenge. Make one materials bag per child and mentor.

Living with an Amputation

Injury and disease are common reasons for amputating a limb.

People with an amputation say that bathing is the hardest daily activity for them.

Most amputees still go to school or work full-time.

93% of amputees own a prosthesis and most use it all day, every day.

Time

Disability awareness activity: 30–45 min; Building challenge: 30–45 min
Lesson 2: Disability Awareness, continued

Warm-Up Questions

- What do you think life would be like with one hand?
- How do you think tools help someone with a disability?

Procedure

1. Introduce the activities for the day — to learn about life with a disability and to build a tool to make picking up keys easier for someone with a prosthetic hand.

2. Disability awareness activity (see handout on next page):
   a. Tape up dominant hand in latex glove. Have kids make a fist, cover with glove, and tape around the bottom.
   b. Try different tasks with just one hand, such as eating Jolly Ranchers, opening a bag of chips, tying shoes, texting on a cell phone, or typing on a computer. To make the task more challenging, pretend that you are at a party and want to look as normal as possible. Can you complete these tasks without drawing too much attention to yourself?
   c. Try activities again while holding a tool in your dominant hand.
   d. Rate the difficulty of each task with and without tools.

3. Building challenge: Pick up key ring using only prosthetic tool.

   Students might find that a hook works best for picking up the key ring. Designs could be improved to be more durable, stable, or easier for the operator to use.

   Adaptations for Amputees

   Engineers at Johns Hopkins University have adapted Guitar Hero III: Legends of Rock for amputees by placing sensors on an amputated limb to detect muscle contraction signals. Players no longer need to press the guitar buttons.

   The Re-Bound Pro is a prosthetic hand adapted for basketball. It is made of a polymer that allows for flexibility and strength.

   Animals can use prosthetics too. Engineers at Hangar Prosthetics and Orthotics built a prosthetic tail for Winter, a dolphin that lost her tail in a crab trap. Winter now lives at the Clearwater Marine Aquarium in Florida.

   a. Introduce task to the group — each student will design their own tool to pick up key ring. They can take the tool home when they are done.
   b. Introduce materials. Describe materials that kids haven’t seen before.
   c. Allow kids to be independent in building the tools. The goal is to introduce them to the basics of construction and assess their comfort level with building. Some kids will require guidance; it is okay to help them with brainstorming and building.
   d. Test effectiveness of the tools and encourage kids to revise their designs.

   Concluding Discussion

   - Disability awareness activity: Discuss which activities were more difficult to do with just one hand. Why were they more difficult? How did the tools help?
     Students will find that tasks that require two hands, such as tying their shoes, will be much more difficult.
     The tools might make it easier to hold small objects.
   - Building challenge: Compare and discuss each design. Which features worked well in each design? Which could be improved?
Lesson 2: Disability Awareness Activity Worksheet

Disability Awareness activity

Instructions
1. Tape up dominant hand in latex glove. Have kids make a fist, cover with glove, and tape around the bottom.

2. Try different tasks with just the use of the nondominant hand, such as eating Jolly Ranchers, opening a bag of chips, tying shoes, texting on cell phone, or typing on computer.

3. Try activities again while holding a tool in your dominant hand.

4. Each time your group performs a task, rank its level of difficulty.

<table>
<thead>
<tr>
<th>Task</th>
<th>Tool</th>
<th>Level of Difficulty on a Scale of 1 to 4*</th>
<th>Observations</th>
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*Scale
1 = as easy as having two functional hands
2 = a bit unnatural but doable
3 = very difficult and requires extreme effort
4 = impossible
Lesson 3: Engineering Design Process

Lesson Objectives
- As a group, determine necessary steps for effective design process
- Building challenge: Design a tool to pick up candy
- Summarize design process concepts with Family Feud-style game

Refresher
In the last lesson, the students experienced the difficulties of living with an amputation and learned about the usefulness of tools in adapting activities for people with disabilities. To begin learning about design and construction, the members of your group each built a tool to help an amputee pick up keys.

What You Need to Know
Designing and building a new tool can be difficult if not approached systematically. The engineering design process simplifies the task and is similar to the scientific method. The steps include:
- defining and researching the problem
- brainstorming design ideas
- building a design prototype
- testing and evaluating the design
- revising the design to correct any problems

This process does not have to occur in a specific order and each step can be performed more than once. For example, it might be necessary to go back to the brainstorming and research phases after a design prototype has been built. The goal for this lesson is to help the kids learn the steps of the engineering design process and to put these steps into practice while building a tool for picking up candy.

Materials
- Possible materials for building challenge include: two-prong hook, disposable putty knife, foam paint brush, clothes pin, plastic bottle, wood dowel, poster board, electrical tape, rubber bands, Velcro, steel band clamp, cable tie
- Poster board and markers
- Paper and pencils for drawing
- Engineering design process game board (see attached)
- Candy for use in scooping activity and as reward for game

Prep Work
- Collect enough building challenge materials for each kid and mentor. Assemble one baggie of materials per child/mentor.
- Distribute enough pencils and paper for each kid for sketching.
- Build engineering design process game board (see attached for instructions).
- Distribute candy to mentors.

Time
Brainstorming and discussion 30 min, Building 30-60 min

What is an engineer?
An engineer uses scientific knowledge, mathematics, and ingenuity to design solutions to technological problems.

There are many types of engineers:
- Electrical
- Chemical
- Computer Science
- Mechanical
- Civil
- Biomedical
- Environmental
- Materials
- Industrial
- Aerospace
- Agricultural

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Lesson 3: Engineering Design Process, continued

Warm-Up Questions

• What are engineers and what do they do?

• When you build something, do you always know how to build it before you start working on it? Does it typically work perfectly the first time?

Procedure

1. Introduce challenge for the day—to build a tool to pick up candy. The kids will get to take home their designs.

2. Ask the kids what they thought of the building activity from the last lesson. You could ask them “Was it challenging? If so, why was it difficult?” The goal is to get them to understand that jumping right into building may not be the best approach, and that it might be easier if they used a process to design their tools.

3. Begin a discussion about the design process. For example, you could ask, “How should we start the design process?” Direct the group towards the concepts of brainstorming, researching, building prototypes, and revising design. Write process steps on poster board.

4. Brainstorm ideas for the tool as a group, deciding on one key feature that everyone must incorporate into their design. Mentor can start a sketch of the design and encourage kids to try sketching themselves or to improve the mentor’s sketch.

5. Introduce the materials box and spend some time examining the materials. Introduce materials they do not know. Revise the sketch now that you know the materials.


7. Once everyone has built a tool, begin testing how effective they are at picking up candy. Allow kids to revise their designs, if time allows.

8. If time allows, play the Engineering Design Process game.

Concluding Discussion

• Compare the different designs at the table. What were the best features of each design? Which features could be improved?

  The students may find that a scoop works best for picking up the candy. Adjusting the size, materials, and angle of attachment of the scoop could help improve the design.

• Which design process steps did we use to build our tools?

  Defining and researching the problem, brainstorming design ideas, building a design proto-

Brainstorming Warm-Up Drill

Want to stimulate creativity? Some kids might need help getting their creative juices flowing. Try this game as a warm-up drill.

Think of a category, such as things that are yellow or TV characters. Toss a ball around the table. As the ball is tossed and caught, each kid must come up with an item that belongs to that category.

Notice how one student’s idea can prompt many more in the same category. Emphasize this collaborative aspect with your group.
Lesson 3: Engineering Design Process, continued

Building the Engineering Design Process Game Board
This is a Family-Feud style game that reviews the steps of the engineering design process. A game board is required for this game. Instructions for assembly are on the right.

Materials
- Printer
- Scissors
- Clear laminate
- Posterboard
- Glue
- Velcro (1" x 1" squares)

Assembly instructions
1. Cut out and laminate the two sets of pieces on the following page.
2. Glue the “Research the Problem,” “Brainstorm Design Ideas,” “Build a Prototype,” “Test/Evaluate the Prototype,” and “Revise the Design” pieces to a poster board. These pieces will be covered with the second set of pieces, labeled with numbers 1-5, so that “Research the Problem” is covered by the piece labeled “1”, “Brainstorm Design Ideas” is covered by “2”, “Build a Prototype” is covered by “3”, “Test/Evaluate the Prototype” is covered by “4”, and “Revise the Design” is covered by “5”.
3. To make the numbered pieces removable, use Velcro to attach the ends of the pieces to the board.

Rules of the game
1. Decide how the kids in your group will compete, either individually or in teams.
2. Each individual or team will take turns to identify a step in the Engineering Design Process.
3. If they correctly identify a step, remove the flap covering that step on the posterboard and give a candy reward. The other team now gets to take a turn.
4. If they do not correctly guess a step, then the other team gets to go.
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<th>Research the problem</th>
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<td>Brainstorm design ideas</td>
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<td>Build a prototype</td>
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<tr>
<td>Test/evaluate the prototype</td>
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<td>Revise the design</td>
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Lessons 4-6: Building a Prosthetic Arm

Lesson Objectives
- Design a prosthetic arm that can pick up olives and a bucket of water
- Evaluate and revise the prosthetic design
- Test the prosthetic design in a timed challenge

Refresher
In Lesson 3, your group learned about the engineering design process, which includes defining and researching the problem, brainstorming design ideas, building a design prototype, testing and evaluating the design, and revising the design to correct any problems. To practice the engineering design process, the students each built a tool to pick up candy.

What You Need to Know
This lesson takes place in three sessions and, by the end of this time, your group will have built a functional prosthetic arm for Laila. The materials available to you are simple and easily found in Afghanistan. While limited in your supplies, there are many design options and examples of past designs can be found in the Lesson 4 Appendix. Since the average Afghan family earns only a fraction of the standard American income, it is important that your design is inexpensive. You can use the materials price list to help your group calculate the cost of your prosthesis.

At the end of this unit, each prosthesis design will participate in a timed challenge and will be evaluated for its functionality. The best design will be the one to pick up the most olives and carry the bucket of water the farthest (without spilling) in one minute per activity.

Tips for construction
SAFETY FIRST! Many of the tools can cause injury if not handled properly. Supervise the use of all tools closely.

Many materials can only be used once. Make sure you are confident in your design before you use cable ties, stretch out springs, cut materials, or drill holes.

Don’t forget about the Engineering Design Process!

Materials
- Materials for prosthetic arm (see Materials List, p.38)
- Tools for constructing designs (see Materials List, p.38)
- Paper and pencils for drawing
- One bucket for each group
- A bowl of whole black olives (8-12) per group

 Prep Work
- Assemble materials box for each group. Include the supply list and price sheet.
- Collect building tools including hammer, screwdriver, drill, etc.
- Print several test sheets per group.
- Pass out pencils and paper for drawing.
- Prepare testing site for design competition (see Lesson 7: Design Competition).

Time
Three sessions, each 60-90 minutes. The final session will also be used for the design competition preliminary round.
Warm-Up Questions

• Based on what we’ve learned from the last few activities, what features should we include in our prosthetic arm?

• Did some materials from the last two projects work better than others?

Procedure

1. Introduce the goal for the next three weeks—to design and build a prosthetic arm for Laila.

2. Reiterate the design process steps.

3. Examine the contents of the materials box and spend some time brainstorming. Research any materials that are unfamiliar. Remind kids about what was learned in building challenges from previous two sessions.

4. Review the proper, safe use of the tools, paying special attention to the drill, awl, and hand saw.

5. As a team, begin building an arm. Sometimes it is easiest to delegate tasks to each kid or to pairs of kids. It might also help to test each component as you are building it. Questions to ask along the way: Is the prosthesis stable? Is the connection between the adaptor and tool sturdy? Can you easily pick up bucket of water? Can you quickly pick up olives?

6. Try to build an arm that meets the following criteria:
   • Comfortable
   • Functional
   • Stable
   • Adaptable
   • Waterproof

7. When the arm is mostly built, have the kids perform the challenge activities. You could ask them “Which features worked well? What needs to be improved?”

8. Fill out the Design Testing Worksheet using the scoring rubric (see Lessons 4-6 Appendix). If you have time, work with the kids to estimate the cost of the prosthesis.

9. Get ready for the design competition! Pick one student to perform each challenge activity and have kids practice using the arm.

Concluding Discussion

• What do you like best about our design? What do you like the least?

• What materials would have been helpful in building this prosthesis?

• What were the strengths of our team? How could we have worked together better?
Lessons 4-6 Appendix: List of materials

It is helpful to organize the materials into one large plastic storage container per team, which doubles as a storage site for the prosthetic arm as it is being constructed. McMaster-Carr Part numbers are included for select items (www.mcmaster.com).

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty needed per container</th>
<th>Approximate Cost</th>
<th>McMaster-Carr Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot; diameter PVC pipe</td>
<td>One piece, 8&quot; in length</td>
<td>$2.00/ea</td>
<td>49035K85</td>
</tr>
<tr>
<td>4&quot; diameter PVC Couple</td>
<td>2 couples</td>
<td>$1.55/ea</td>
<td>9102K234</td>
</tr>
<tr>
<td>Two-prong hook</td>
<td>1 hook</td>
<td>$0.75/ea</td>
<td>1728A84</td>
</tr>
<tr>
<td>One-prong hook</td>
<td>1 hook</td>
<td>$0.75/ea</td>
<td>1728A82</td>
</tr>
<tr>
<td>Extension Spring</td>
<td>2 springs</td>
<td>$1.00/ea</td>
<td>9654K261</td>
</tr>
<tr>
<td>Elastic Bandage</td>
<td>1 bandage</td>
<td>$1.90/ea</td>
<td>54845T112</td>
</tr>
<tr>
<td>Disposable Putty Knife</td>
<td>1</td>
<td>$0.60/ea</td>
<td>3546A41</td>
</tr>
<tr>
<td>L-Shape Brace</td>
<td>2</td>
<td>$0.30/ea</td>
<td>1558A12</td>
</tr>
<tr>
<td>Hook and Loop (Velcro)</td>
<td>one strip ~6-8&quot; in length</td>
<td>$0.75/ea</td>
<td>9273K141</td>
</tr>
<tr>
<td>Dowel Pin</td>
<td>4-6 pins</td>
<td>$0.05/ea</td>
<td>97195A847</td>
</tr>
<tr>
<td>Steel Band Clamp</td>
<td>1</td>
<td>$1.25/ea</td>
<td>5420K4</td>
</tr>
<tr>
<td>Foam Paint Brush</td>
<td>1 brush</td>
<td>$0.60/ea</td>
<td>7754T42</td>
</tr>
<tr>
<td>1/4&quot; Wood Dowel</td>
<td>One piece 5-10&quot;</td>
<td>$0.50/ea</td>
<td>9683K14</td>
</tr>
<tr>
<td>Cotton Rag</td>
<td>1 rag</td>
<td>$0.10/ea</td>
<td>7366T15</td>
</tr>
<tr>
<td>Electrical Tape</td>
<td>1 roll</td>
<td>$0.60/roll</td>
<td>7619A11</td>
</tr>
<tr>
<td>Rubber Bands</td>
<td>~20 rubber bands</td>
<td>$0.01/ea</td>
<td></td>
</tr>
<tr>
<td>Sponge</td>
<td>2 sponges</td>
<td>$0.70/ea</td>
<td>7356T1</td>
</tr>
<tr>
<td>Masking Tape</td>
<td>1 roll</td>
<td>$1.80/roll</td>
<td>76275A13</td>
</tr>
<tr>
<td>Latex Glove</td>
<td>1 glove</td>
<td>$0.10/pair</td>
<td>6072T3</td>
</tr>
<tr>
<td>Clothes Pins</td>
<td>4 clothes pins</td>
<td>$0.10/ea</td>
<td>12275T53</td>
</tr>
<tr>
<td>Cable Ties</td>
<td>10 ties</td>
<td>$0.05/ea</td>
<td>7130K31</td>
</tr>
<tr>
<td>Cotton Balls</td>
<td>10 cotton balls</td>
<td>$0.01/ea</td>
<td></td>
</tr>
<tr>
<td>Ruler</td>
<td>1</td>
<td>$1.15/ea</td>
<td></td>
</tr>
<tr>
<td>Transparent (Packing) Tape</td>
<td>1 roll</td>
<td>$1.75/roll</td>
<td></td>
</tr>
<tr>
<td>Permanent Marker</td>
<td>1 marker</td>
<td>$1.00/ea</td>
<td></td>
</tr>
<tr>
<td>Wood Shims</td>
<td>5 pieces</td>
<td>$1.50/ea</td>
<td>9704K8</td>
</tr>
<tr>
<td>Wire hanger</td>
<td>1</td>
<td>$0.25/ea</td>
<td></td>
</tr>
<tr>
<td>Pantyhose</td>
<td>1 knee high</td>
<td>$1.50/ea</td>
<td></td>
</tr>
<tr>
<td>20 oz plastic soft drink bottle</td>
<td>1 per box</td>
<td>free</td>
<td></td>
</tr>
</tbody>
</table>

Optional tools, shared amongst groups. **All must be used with close adult supervision!**

- Hammer
- Awl
- Scissors
- Battery-powered drill
- Screw drivers
- Drill bits
- Hand saw
- Pliers or Vise-Grip
Lessons 4-6 Appendix: Design Testing Worksheet

Each time your group tests your design, fill out one of these worksheets.

Group Name ___________________________ Test # _________ Date ____________

<table>
<thead>
<tr>
<th>Design Requirement</th>
<th>Score (points)</th>
<th>Comments on how to improve design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Does it work?)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strong /Durable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comfortable,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appropriate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size/Weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural-looking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy to Use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waterproof</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Design Score

Approximate Design Cost $ refer to the price list on page XX

OVERALL SCORE total design score divided by approximate design cost
## Lessons 4-6 Appendix: Prosthetic Hand Design
### Scoring Rubric

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>Does not complete task at all</td>
<td>Task completed, but had major problems that should be fixed</td>
<td>Minor problems still present (e.g., grapes sometimes roll away)</td>
<td>Task completed smoothly!</td>
</tr>
<tr>
<td><strong>Strong/Durable</strong></td>
<td>Starts to break before putting it on</td>
<td>Can put it on but breaks when trying to accomplish the task</td>
<td>Only a few parts seem to bend after a few tests</td>
<td>Very strong! This arm can be used repeatedly without breaking at all!</td>
</tr>
<tr>
<td><strong>Comfortable</strong></td>
<td>OUCH!</td>
<td>Feels fine at first, hurts when doing task</td>
<td>Fine when doing task, but hurts after awhile</td>
<td>I could wear this all day!</td>
</tr>
<tr>
<td><strong>Natural-looking</strong></td>
<td>I would be embarrassed to wear this</td>
<td>I would wear this to do the task, but then take it off afterwards</td>
<td>Approaches anatomy of human arm</td>
<td>Resembles human arm (Same size and skin tone as other arm)</td>
</tr>
<tr>
<td><strong>Easy to Use</strong></td>
<td>Arm is difficult to get on and off. Can’t do any tasks with it; it is hard to control</td>
<td>Repeated practice is needed before a task can be accomplished</td>
<td>Arm can be put on easily with one hand. It moves easily.</td>
<td>Arm is easy to get on with one hand. Can move arm very easily and with a few adjustments, this arm could do many other tasks!</td>
</tr>
<tr>
<td><strong>Adjustable</strong></td>
<td>There is no way to modify this prosthesis to fit Laila as her arm grows</td>
<td>Can only be modified to fit a very small size range or may be very difficult to modify</td>
<td>May be modified to fit a wide range of sizes, but the procedure is complicated.</td>
<td>Very easy to modify this prosthesis so that the socket fits snugly on a larger or smaller arm.</td>
</tr>
<tr>
<td><strong>Waterproof</strong></td>
<td>No parts of this prosthesis are waterproof – would likely need to be completely replaced after getting caught in a rainstorm.</td>
<td>Has some waterproof features but is inadequate.</td>
<td>Most or all parts of the arm are waterproof, but will still need to be replaced with time.</td>
<td>All parts of this arm are waterproof.</td>
</tr>
</tbody>
</table>
Lesson 7: Design Competition

Lesson Objectives

• Student groups have a chance to experience real-world testing of their prostheses
• Successful designs can take many different forms
• Celebrate the hard work that went into each design

Refresher

Each group of students was challenged to design a prosthesis that could:

☐ Carry a two-liter bucket of water a distance of five meters and placed on a table one meter high

☐ Pick up individual olives and transfer them from a bowl to mouth

What You Need To Know

To evaluate the prostheses, all groups will participate in a timed challenge. Select one student to perform each of the tasks listed above. Students will be given one minute to complete each task.

If you desire, the design challenge can be performed with each group of students two or three times, with group given the opportunity to make minor revisions and improvements to their prosthesis between rounds.

The winning group of this design competition will be the one that scores the most points in the bucket-carry activity and picks up the most olives or grapes.

Materials

☐ Three tables, each approximately one meter high
☐ Stopwatch
☐ Clipboard, scorecard, and pencil
☐ Bucket with two liters of water
☐ Mop & bucket and/or paper towels for cleaning up spills
☐ Bowl (plastic or paper cereal bowl is ideal)
☐ Double-sided tape
☐ Several jars of whole black olives (or, alternatively, several bags of fresh grapes)

Prep Work

☐ Assemble materials.
☐ Print copies of the Design Competition Score Sheet, at least one per group.

Time

90 minutes should be sufficient for several preliminary rounds and a final round.

Tips for the design competition

Encourage teamwork. Allow all members of the group a chance to participate in a timed trial.

Small prizes such as ribbons or medals can give the competition a more “official” flair.

Invite non-participating youth to attend the competition. This sparks interest in participating in the next Get a Grip session!
Lesson 7: Design Competition, continued

Procedure
Each group will be asked to participate in a timed trial for the two challenge tasks: carrying a bucket of water, and picking up olives and transferring them from bowl to mouth.

A judge should be appointed to time each challenge task and to tally points.

Challenge Task #1: Carry bucket of water
1. Set up two tables so that they are five meters apart. The tables should be approximately one meter high.
2. This competition is **one minute** in length.
3. The bucket starts on the floor near one table.
4. When the timer says “Go!” the student wearing the prosthesis picks up the bucket without the use of his or her other hand.
5. He or she must place the bucket on the table and then carry the bucket across the room towards the other table.
6. The student places the bucket on the floor near the other table.
7. The student lifts the bucket from the floor and places it on the table. This scores one point.
8. They then carry the bucket back across the room.
9. Repeat steps 5-7 as many times as you can in one minute, scoring a point for each time the bucket is placed on the table.
10. As a penalty, if water spills out of the bucket, another teammate has to clean up the spill before the competitor can proceed.

Challenge Task #2: Pick up olives
1. Using double-sided tape, tape the bowl to the table. This will prevent the bowl from sliding around during the challenge. Place 10 olives (or grapes) in the bowl.
2. This competition is **one minute** in length.
3. When the timer says “Go!” the student uses the prosthesis to pick up one olive or grape from the bowl. He or she cannot use their other hand to hold the bowl or touch the olive in any way. If the olive falls out of the bowl, do not put it back in the bowl.
4. Once the olive has been picked up, the student has to put the olive in their mouth and then spit the olive back into the bowl. This scores one point.
5. Repeat steps 2 and 3 as many times as possible in one minute, scoring one point for each olive placed in his or her mouth.
6. As a penalty, if all the olives fall or bounce out of the bowl, the task is over and the student scores no more points.

Concluding Discussion
When the competition is over, encourage the mentors to replay the steps that led to a successful outcome for each group. Remind the students that they overcame initial feelings of “I can’t do this” and built a functional prosthetic arm!
# Design Competition Activity Score Sheet

Use this sheet to record points earned in the Design Competition Activity

<table>
<thead>
<tr>
<th>Group Name</th>
<th>Challenge Task #1: Bucket of water (points)</th>
<th>Challenge Task #2: Pick up olives (points)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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