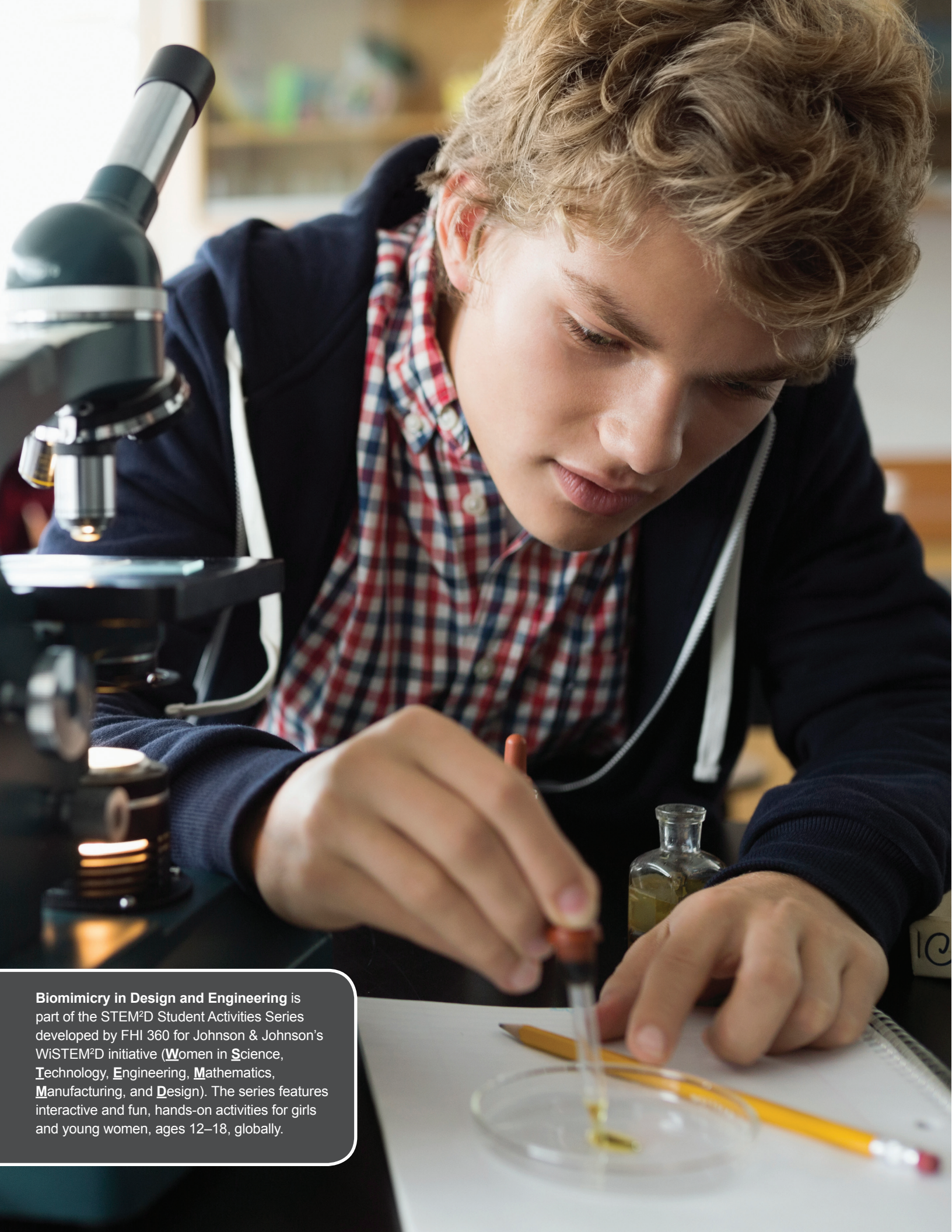


BIOMIMICRY IN DESIGN AND ENGINEERING

STEM²D Topics:
Design
Engineering

Target Population:
Students, ages 14–18



Biomimicry in Design and Engineering is part of the STEM²D Student Activities Series developed by FHI 360 for Johnson & Johnson's WiSTEM²D initiative (**W**omen in **S**cience, **T**echnology, **E**ngineering, **M**athematics, **M**anufacturing, and **D**esign). The series features interactive and fun, hands-on activities for girls and young women, ages 12–18, globally.

Biomimicry in Design and Engineering

STEM²D Topics: Design and Engineering

Target Population: Students, ages 14–18

ACTIVITY DESCRIPTION

Students will learn how nature and the living world provide inspiration for addressing the world's challenges. Using creative thinking and problem-solving skills, students will design a structure or product inspired by nature.

ESTIMATED TIME



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

STUDENT DISCOVERIES

Students will:

- ☐ Participate in a team-based learning experience.
- ☐ Learn how nature influences design and engineering.
- ☐ Build important STEM²D skills, such as creative thinking, critical thinking, and problem solving.
- ☐ Realize that STEM²D offers diverse and exciting career opportunities.
- ☐ Have fun experiencing STEM²D.

GETTING READY

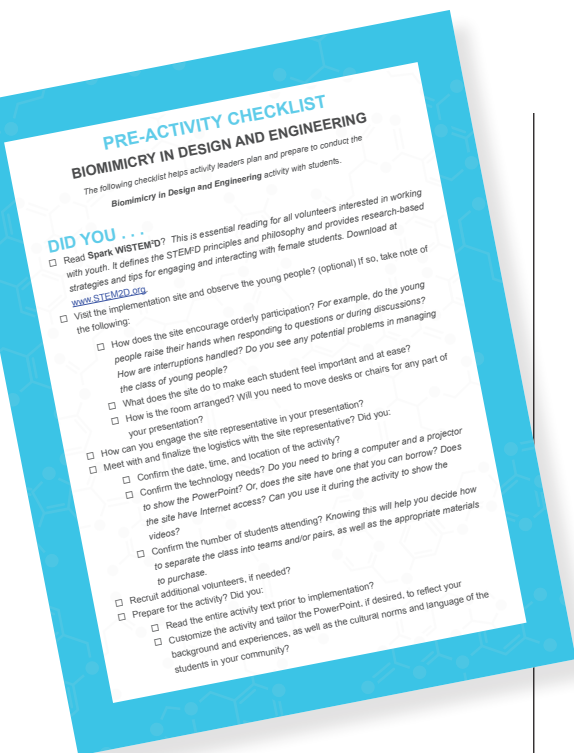
Materials

- ☐ Computer with projector and Internet access for the presentation, plus additional computers/devices connected to the Internet for student use
- ☐ PowerPoint: Biomimicry in Design and Engineering
- ☐ Pre-Activity Checklist
- ☐ Tell My Story Form
- ☐ Student Handout: Biomimicry Challenge, *1 per student*



STEM²D Skills

- ☐ Collaboration
- ☐ Communication
- ☐ Creative Thinking
- ☐ Critical Thinking
- ☐ Decision Making
- ☐ Problem Solving
- ☐ Teamwork
- ☐ Presentation



- ☐ Student Handout: Design Ideas, *1 per student*
- ☐ Student Handout: Biomimicry Resources, *½ sheet per team*
- ☐ Pen/pencil, *1 per student*
- ☐ Flip chart paper, *1 (or more) page per team*
- ☐ Colored markers, *1 pack per team*

Estimated Materials Cost:

Activity leaders can expect to incur less than \$10.00 (excluding optional items) in materials costs when completing this activity with 25–35 students organized into teams of four to five students.

Activity Leader Preparation

- ☐ 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 female students. Download at www.STEM2D.org.
- ☐ Review the **Pre-Activity Checklist** (at the end of this document) for details and specific steps for planning, preparing, and implementing this activity.
- ☐ See the **STEM²D Student Activities Overview** for additional information.

STEP-BY-STEP INSTRUCTIONS: BIOMIMICRY IN DESIGN AND ENGINEERING

1. Welcome and Introduction (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, Mathematics, Manufacturing, and Design.
- ☐ Ask students and other volunteers to introduce themselves and state their favorite area of STEM²D.

- **(Today's Plan Slide)** Review the agenda. Explain that today students will learn how nature influences design and engineering. Share that they will be able to put their own skills to use in a team design activity.

2. **Career Awareness: Design and Engineering in the World of Work (10 minutes)**

- **(Design and Engineering in the World of Work Slide)**
Initiate an opening discussion and brainstorming activity. Consider asking:
 - How do you think design and engineering are used every day in the workplace?
 - What kinds of careers do you think people with an interest, aptitude for, or degree in design or engineering would have?
- **(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:
 - When/why you developed an interest in design and engineering.
 - The classes/courses you took in secondary school.
 - 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 design and engineering and what you do on a typical work day.*
- Weave in facts about design and engineering and STEM²D careers:
 - Tell the students that your career is only one of the many careers available in the STEM²D disciplines—science, technology, engineering, mathematics, manufacturing, and design.
 - Explain that STEM²D careers are high-demand, high-growth careers and are predicted to remain in demand over the next 10 years.
 - Share a few Johnson & Johnson job titles and careers.

Tips for Facilitators on STEM²D Careers

- Share with students that there are many different kinds of careers related to STEM²D
- STEM²D careers related to this activity:
 - Environmental engineer
 - Mechanical engineer
 - Automotive engineer
 - Wildlife biologist
 - Aquatic biologist
 - Industrial designer

KEY WORDS

- ☐ Biomimicry
- ☐ STEM²D
- ☐ Sustainable

3. Content Presentation: Learning About Biomimicry (10 minutes)

- ☐ **(Biomimicry Slide)** Ask students what they think biomimicry means. Choose a few students with hands raised to share their thoughts.
- ☐ **(What is Biomimicry? Slide)** Explain:
 - **Biomimicry** is an approach to innovation that seeks sustainable solutions to human challenges by imitating nature's patterns and strategies.
- ☐ Define sustainable: **Sustainable** means to be capable of being maintained at a steady level without exhausting natural resources or causing severe ecological damage.
- ☐ **(Why Biomimicry? Slide)** Ask students why engineers and designers might use biomimicry. Explain that biomimicry can help solve problems to challenges faced by humans. Consider referencing a famous quote by Albert Einstein: "Look deep into nature, and then you will understand everything better."
- ☐ **(Biomimicry in Consumer Products Slide)** Ask students to give their thoughts and observations about the images shown. Provide your perspective as well as a conversation starter if needed. Using the following text, explain:
 - Velcro was invented by Swiss engineer George de Mestrel in 1941 after he removed burrs from his dog and decided to take a closer look at how they worked. The small hooks at the end of the burr needles inspired him to create Velcro.
- ☐ **(Biomimicry in Architecture Slide)** Ask students to share their thoughts and observations about the images shown. Provide your perspective as well as a conversation starter if needed. Then explain:
 - We generally think of termites as destroying buildings, not helping design them. But the Eastgate Building, an office complex in Harare, Zimbabwe, has an internal climate control system originally inspired by the structure of termite mounds.
 - The operation of buildings represents 40 percent of all the energy used by humanity, so learning how to design them to be more sustainable is vitally important.
 - The architect collaborated with engineers to design

Eastgate, which uses 90 percent less energy for ventilation than conventional buildings its size and has already saved the building owners over \$3.5 million dollars in air conditioning costs.

- **(Biomimicry in Transportation Slide)** Ask students to make observations about the images shown. Provide your perspective as well as a conversation starter if needed. Then explain:
 - The Shinkansen Bullet Train was the fastest train in the world, traveling 200 miles per hour. The problem? Noise. Air pressure changes produced large thunder claps every time the train emerged from a tunnel, causing residents one-quarter a mile away to complain. The train's chief engineer and an avid bird-watcher asked himself, "Is there something in nature that travels quickly and smoothly between two very different mediums?" They re-modeled the front-end of the train after the beak of kingfishers, which dive from the air into bodies of water to catch fish, with very little splash. This resulted not only in a quieter train, but a train that could travel 10 percent faster and use 15 percent less electricity.
- **(Biomimicry in Healthcare Slide)** Ask students to make observations about the images shown. Provide your perspective as well as a conversation starter if needed. Then explain:
 - In the late 1800's people were apt to use the sharpened ends of quills or slivers of wood to clean between their teeth because silk dental floss was too pricey. Johnson & Johnson decided to use the excess silk left over from its suture-manufacturing business to make a more affordable version of floss for the average consumer. It is interesting to note that Porcupine quills, with their ease of entry, also serve as a model for injection and suture needles.
 - Mussels possess the unique ability to attach to wet, solid surfaces such as rocks, fish, and boats and are able to withstand strong wind and even waves. The remarkable adhesive powers of the mussels inspired the discovery of medical adhesives. In 1998, Ethicon Inc., introduced

TIPS FOR MAKING CONNECTIONS

Encourage students to:

- Ask questions if they don't understand
- Summarize what they have learned
- Explain their thinking process aloud
- Describe examples of biomimicry they see in their everyday life

TIPS FOR PROVIDING FEEDBACK TO STUDENTS

- Be sensitive when providing feedback.
- Provide positive feedback on the design itself.
- Ask students what challenges they may face in bringing their design to life.
- Ask students what they would add or change in their design if they had more time



a breakthrough alternative to traditional stitches.

Dermabond® became the first FDA-cleared topical skin adhesive used to close up cuts that would otherwise require sutures or staples.

4. Learning Activity: Biomimicry Challenge (20 minutes)

- **(Biomimicry Challenge Slide)** Introduce the challenge using the instructions below. Indicate:
 - Today, we are going to do a team-based activity that simulates how nature inspires designers or engineers.
 - Your challenge is to work as a team to design a structure, mode of transportation, or consumer product that is based on something in nature and solves a human challenge.
 - Remember, the termite mound was built by termites to help regulate temperature. The building in Africa was modeled after the termite mound, and the design helps lower electricity costs for a large building in a hot climate.
 - In a moment, I will share some photos. Your team may use these photos as inspirations in your design.
 - Alternately, you may use the Internet to perform research. Inspiring websites are listed on the Biomimicry Resources handout.
 - Brainstorm and sketch some potential designs on the Design Ideas handout.
 - Select one design to present as a team to the whole group.
 - Draw your team's final design on the flip chart paper using the materials provided.
 - You will have 15 minutes for this task.
 - We will end the challenge with team presentations. One person from each team will share the design and an explanation of why it is a sustainable solution to a human challenge. Each team will have 2 minutes to present to the class.
- Break the students into groups of 4–5 and distribute the Student Handouts, flip chart paper, and markers.
- **(Inspirations in Nature Slide)** Show the images depicting animals/plants that can be used as inspiration.

- For each image in Row 1 (left to right), give a brief description using the following text:
 - Mushrooms can be used as inspiration for housing—the shape of the mushroom cap allows mushrooms to absorb a large amount of sunlight to convert to energy.
 - The butterfly is lightweight, can fly long distances, and can maneuver easily. Its design can be used as inspiration for airplanes.
 - A shark’s skin is made up of countless overlapping scales. The scales have grooves that allow water to pass by faster. The sharkskin has been used to help design swimsuits.
 - A mole is known for its tunnel building. Tunnel building is a solution being explored in cities with severe traffic problems. In Los Angeles, California, Elon Musk, the co-founder of Tesla, is currently building a network of tunnels under the city that will someday transport people from one place to another.
- For the images in Row 2 (left to right), indicate:
 - The cells in beehives are already being used as inspiration for capsule hotels where people sleep in small adjacent capsules instead of hotel rooms.
 - Spiders have the ability to travel vertically and horizontally and also travel long distances. The hairs on their feet help grip the surface, and they create silk parachutes using techniques similar to those used in creating a web. These characteristics may one day change how humans move around the earth.
 - Beavers have a thick layer of blubber that keeps them warm while they’re diving and swimming in their water environments. Their fur is so dense that it traps warm pockets of air in between the layers, keeping these aquatic mammals not only warm, but dry. Engineers are using these features to help design wetsuits for surfing—when an athlete moves frequently between air and water environments.
 - The front edge of a whale fin has bumps that greatly increase its efficiency, reducing drag and increasing lift.

Companies are applying the idea to wind turbine blades, cooling fans, airplane wings, and propellers.

- ☐ Have the teams get started on the challenge. Remind teams that they have 15 minutes to complete the challenge.
- ☐ Walk around the room and observe the teams. Encourage group collaboration and ensure all students are participating in the task. Ask questions about the teams' designs. Answer questions as needed. If the teams are using the Internet for research, remind them to leave time for designing.
- ☐ Indicate when 5 minutes remain for the challenge. Remind any individual groups that seem to be behind that they may need to speed up their work to complete the task on time.
- ☐ After 15 minutes, call time.

5. **Student Presentations (10 minutes)**

- ☐ Initiate the presentations. Remind students that each team has 2 minutes to present, and they need to explain their design and why it is a sustainable solution to a human challenge.
- ☐ Ask for a volunteer to be the first presenter. Request that the presenter stand where everyone in the room can see them.
- ☐ Provide brief feedback and/or encourage students to respond to the design.
- ☐ Repeat the process until all groups have shared their designs.

6. **Student Reflection (5 minutes)**

- ☐ **(Reflection Slide)** Ask students to reflect on the activity. Have them spend a few minutes thinking about the following questions:
 - What did you learn about Biomimicry in design and engineering?
 - What role do you think biomimicry will have in how we may live in the future?
 - Can you see yourself as a STEM²D professional? Why or why not?
 - What would you need to do to make that happen?
- ☐ Recap key lessons for the students. You may choose to express your own thoughts or use the following text as a guide:
 - Nature and the living world are providing countless



inspirations for new inventions that are helping solve challenges to problems faced by humans.

- Today we had the opportunity to learn about biomimicry and to create an invention that one day in the future may become a reality.
- Thank students for joining you today and encourage them to continue exploring careers in STEM²D.

Extended Learning

Here are a few ways to extend the learning:

- Have students build their design from recycled or natural materials.
- Have students design a structure to sustain human life on another planet.
- Encourage students to explore biomimicry in the areas of communications, medicine, and technology.

Key Words

Biomimicry—Biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies.

STEM²D—Science, Technology, Engineering, Mathematics, Manufacturing, and Design.



Sustainable—Capable of being maintained at a steady level without exhausting natural resources or causing severe ecological damage.

Resources and References

The following resources provide additional information or activities. They may also be used to show additional examples of biomimicry.

- Ask Nature: <https://asknature.org/>
- Biomimicry—Designing to Model Nature: <https://www.wbdg.org/resources/biomimicry-designing-model-nature>
- Biomimicry in Engineering: <http://tryengineering.org/lessons/biomimicry.pdf>
- Biomimicry Institute: <https://biomimicry.org/>
- Brilliant Bio-designs: 14 animal-inspired inventions <http://www.momtastic.com/webecoist/2011/01/14/brilliant-bio-design-14-animal-inspired-inventions/>
 - Nine incredible buildings inspired by nature: <http://www.bbc.com/earth/story/20150913-nine-incredible-buildings-inspired-by-nature>

PRE-ACTIVITY CHECKLIST

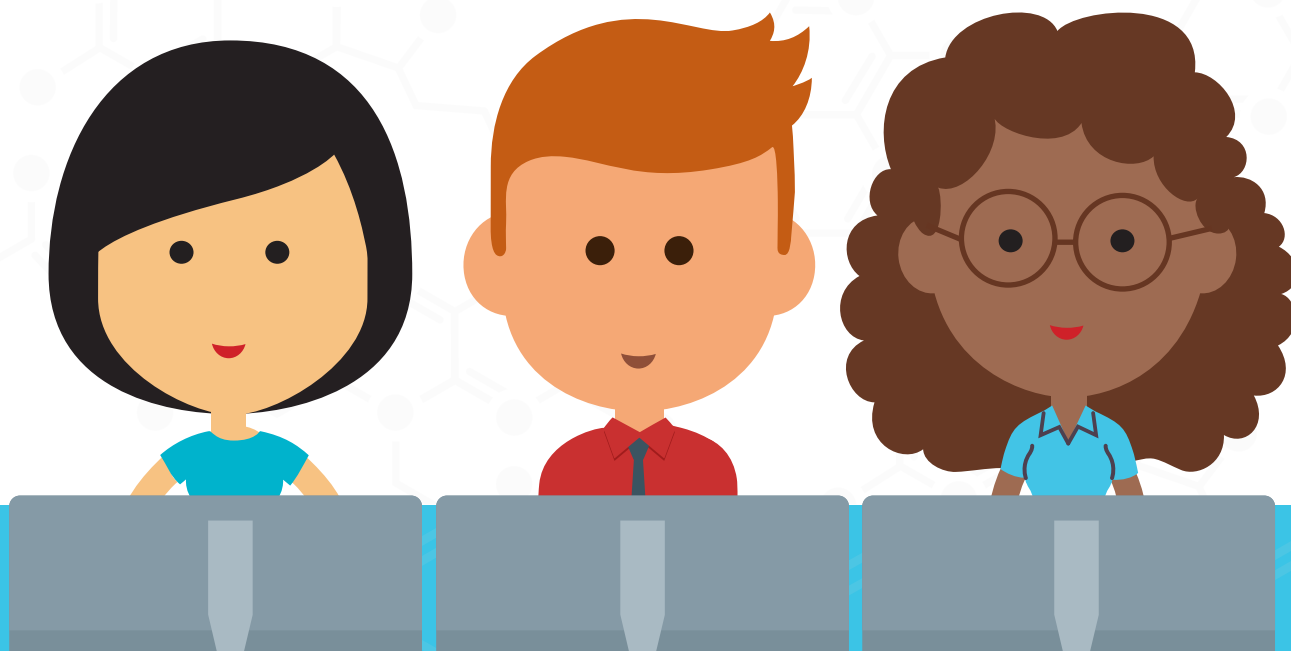
BIOMIMICRY IN DESIGN AND ENGINEERING

*The following checklist helps activity leaders plan and prepare to conduct the **Biomimicry in Design and Engineering** 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 female students. Download at www.STEM2D.org.*
- ☐ 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 in 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 and a projector to show the PowerPoint? Or, does the site have one that you can borrow? Does the site have Internet access? 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 and/or pairs, as well as the appropriate materials to purchase.*
- ☐ Recruit additional volunteers, if needed?
- ☐ Prepare for the activity? Did you:
 - ☐ Read the entire activity text 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?

- ☐ 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**).*
- ☐ Practice your presentation, including the hands-on, minds-on activity? Did you:
 - ☐ Do the activity? Make sure you can explain the concepts to students, if needed, and that you know the correct answers?
- ☐ Obtain the required materials? (*see the **Materials and Estimated Materials Costs** sections*)
- ☐ Set up the site appropriately for the activity? Did you:
 - ☐ Make sure tables and chairs are arranged to accommodate teams of four to five students?
 - ☐ If additional volunteers are available, assign adults to specific teams?
 - ☐ Set up the computer and projector for the PowerPoint presentation? Be sure that an Internet connection is 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 prepare to talk about their STEM²D interests, education, and career path in a relevant and personal way.

ABOUT YOU

Name: _____

Job Title: _____

Company: _____

When/Why did you become interested in STEM²D? _____

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

FUN FACT

Share a little about your background. Ideas:

- Share a memory from childhood when you first had your spark or interest in STEM²D.
- Detail your journey, highlighting 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.* _____

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

BIOMIMICRY CHALLENGE

Student Handout

1. Work together with your group to design a structure, mode of transportation, or consumer product based on something in nature that solves a human challenge.
2. Use the photos depicted in the PowerPoint presentation as inspirations for the design. Alternately, use the Internet to perform research; websites are listed on the Biomimicry Resources handout.
3. Brainstorm and sketch some potential designs on the Design Ideas handout.
4. Select one design to present as a team to the whole group.
5. Draw your group's final design on the provided flip chart paper using the materials provided.
6. One person from each group will share their group's design and an explanation of why the design is a **sustainable** solution to a human challenge. *TIP! Sustainable: to be capable of being maintained at a steady level without exhausting natural resources or causing severe ecological damage.*
7. Each group will have 2 minutes to present to the class.
8. Keep an eye on the time to make sure you leave enough time to draw your design to share with the whole group.

DESIGN IDEAS

Student Handout

BIOMIMICRY RESOURCES

Student Handout

Ask Nature: <https://asknature.org/>

Biomimicry—Designing to Model Nature: <https://www.wbdg.org/resources/biomimicry-designing-model-nature>

Biomimicry Institute: <https://biomimicry.org/>

Brilliant Bio-designs: 14 animal-inspired inventions <http://www.momtastic.com/webcoist/2011/01/14/brilliant-bio-design-14-animal-inspired-inventions/>

Nine incredible buildings inspired by nature: <http://www.bbc.com/earth/story/20150913-nine-incredible-buildings-inspired-by-nature>

BIOMIMICRY RESOURCES

Student Handout

Ask Nature: <https://asknature.org/>

Biomimicry—Designing to Model Nature: <https://www.wbdg.org/resources/biomimicry-designing-model-nature>

Biomimicry Institute: <https://biomimicry.org/>

Brilliant Bio-designs: 14 animal-inspired inventions <http://www.momtastic.com/webcoist/2011/01/14/brilliant-bio-design-14-animal-inspired-inventions/>

Nine incredible buildings inspired by nature: <http://www.bbc.com/earth/story/20150913-nine-incredible-buildings-inspired-by-nature>

