ROBOT REVOLUTION™

Supported by Google.org

TEACHER RESOURCE PACKET

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ABOUT *ROBOT REVOLUTION*

We are in the midst of a revolution in our society's relationship with the robots we create. In a high-touch, high-tech environment, you have an unprecedented opportunity to engage with real robots, witness their astonishing skills and ponder their life-like qualities. *Robot Revolution*, supported by Google.org, transforms the way you think about robots as well as encouraging and empowering you to envision your own role in creating and using technology positively as the future unfolds.

As you get your hands and mind involved in the world of robots, you'll see the rich possibilities the future holds for those with the spirit of innovation. This exhibition is designed to increase awareness and appreciation of robots as well as interest and involvement in science, technology, engineering and math (STEM) topics, particularly the field of robotics.

The exhibit is divided into different zones that highlight the distinct attributes of robots, including:

- Cooperation: Robots can collaborate with us, as well as with other robots.
- Smarts: The programming of robots enables them to sense, plan and act to meet a goal.
- Skills: There are a variety of ways that robots can grasp, grip and interact physically with their environment.
- Locomotion: Discover a surprising array of ways that robots can get around.

The exhibit zones contain functional robots, hands-on interactives, videos and graphics designed to help you explore further. Complementing and supporting these zones is a stage that offers scheduled demonstrations of robots; a robot garage where technicians repair robots in real time in front of guests; and a build-a-bot area, where you can build a simple robot.

EXHIBIT GOALS AND MESSAGES

Robot Revolution is designed to:

- Encourage personal understanding of and connection with robots.
- Showcase diverse examples of robot applications in daily and future life.
- Offer opportunities for hands-on interaction with real robots.
- Highlight the innovative spirit and evolving nature of robotics.
- Engage K-12 students in 21st Century skills and STEM content.

The key messages of *Robot Revolution* are:

- The robot revolution is happening now.
- Robots will transform how we live, work and play.
- Robots, no matter their function, capabilities or design, operate in similar ways: they SENSE, PLAN and ACT.
- Robots serve as a mirror through which we see ourselves.
- Robotics is a creative field in a continuous state of development and discovery.
- No matter your age or experience, you can be involved in robotics.

NEXT GENERATION SCIENCE STANDARDS CONNECTIONS

Robot Revolution is aligned with the following Next Generation Science Standards:

Science and Engineering Practices:
- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Constructing explanations and designing solutions
- Obtaining, evaluating and communicating information

Crosscutting Concepts:
- Cause and effect
- Systems and system models
- Structure and function

Disciplinary Core Ideas:
- PS4: Waves and their applications in technologies for information transfer
- ETS1: Engineering design

CLASSROOM LESSONS

To enhance a *Robot Revolution* field trip, teachers can use free classroom lessons before and after their visit.

What is a Robot?: Students unveil their personal interactions with robots and understand how robots assist with real life scenarios.

Robot Brains: Explore the intricacies of robotic programming through an activity where students act as robots and programmers.

Robot Bodies: Discover how robotic "hands" are shaped in different ways depending on their intended function.

Robot Senses: Explore how robot sensors can either mimic human sensors or do things that humans can't do.

Robots and Society: Learn about how different peoples' values and perspectives shape how robots are developed and used.

In addition, the ***Robot Revolution* Exhibit Guide** lesson focuses your field trip to *Robot Revolution*. Students use a worksheet to record their observations and experiences in the exhibit then complete a follow-up writing exercise back in the classroom.

ROBOT REVOLUTION ADDITIONAL RESOURCES

GENERAL WEBSITES

Institute of Electrical and Electronics Engineers Robotics Newsletter
http://spectrum.ieee.org/static/newsletters-signup

Lego Engineering
www.legoengineering.com/

NASA Robotics
http://robotics.nasa.gov

National Robotics Week
www.nationalroboticsweek.org/index.php

PBS Design Squad
http://pbskids.org/designsquad

Programming

Hour of Code
http://code.org/

Raspberry Pi Programming
www.raspberrypi.org/

RobotC Programming
www.robotc.net/

Scratch Programming
https://scratch.mit.edu/

Online community for Scratch educators
http://scratched.gse.harvard.edu/

ROBOTICS KITS

Cublets Robotics
www.modrobotics.com/education/#lesson-plans

TI-83 calculator robots
www.smallrobot.com/robot-kit.html

SmartBot phone robot kit
www.overdriverobotics.com/

PROGRAMMING-RELATED IPAD APPS

Daisy the Dinosaur
www.daisythedinosaur.com/

Hopscotch
https://www.gethopscotch.com/

Cargo-Bot
http://twolivesleft.com/CargoBot/

ROBOTICS COMPETITIONS

Best Robotics, Inc.
http://best.eng.auburn.edu/

Bot Ball
www.botball.org/

FIRST LEGO League
www.firstlegoleague.org/

MATE Underwater Robotics
http://www.marinetech.org/rov-competition/

Robofest
http://www.robofest.net/

US First Robotics
http://www.usfirst.org/

Vex Robotics Competition
http://www.vexrobotics.com/competition/

WHAT IS A ROBOT?

AT A GLANCE Students will reveal their personal interactions with robots and compare their interactions and thoughts with how robots are evolving and assist with real-life scenarios.

OBJECTIVES

Students will:

- Create a definition of robot.
- Discover four different categories of robots and how they interact with their surroundings.
- Illustrate a robot's build (form) based upon a specific set of parameters (function).

KEY VOCABULARY

Robot, Programmer, Code

NEXT GENERATION SCIENCE STANDARDS

Science and Engineering Practices:

- Asking questions and defining problems
- Developing and using models
- Analyzing and interpreting data
- Constructing explanations and designing solutions
- Obtaining, evaluating, and communicating information

CROSSCUTTING CONCEPTS:

- Patterns
- Systems and system models
- Structure and function

DISCIPLINARY CORE IDEAS:

- MS-PS4: Waves and their applications in technologies for information transfer
- MS-ETS1: Engineering design

PACE YOURSELF

- 45 minutes

ADVANCE PREPARATION

Print out a classroom set of the Robot Comparison Venn diagram and copies of the Robot Scenarios.

MATERIALS

Per student:

- Paper
- Drawing utensils

WHAT YOU NEED TO KNOW

When you hear the word robot, the first visual that might come to mind is something that looks like the picture to the right. As the robotics industry continues to evolve and grow, this stereotypical image and misconception starts to dissolve. If not this image, then what exactly is a robot? To complete their tasks, **robots** have to sense, plan and act. Robots use different kinds of sensors to collect the information they need. Software processes this information so the robot can plan a response. Then they act to get the job done. The person that instructs or programs a robot is called a **programmer**. Programmers use a specific "language" called code to interact with a variety of robots through a computer or software system.

Robots come in different shapes and sizes depending on the activities the robots are intended to carry out. During the design process, engineers consider functionality when creating the form and build of the robot. In the Robot Revolution exhibit, robotics is divided into four different categories: industrial robots, social robots, telerobotics and mobile robots.

Industrial Robots

Robotic companies, such as FANUC, are the largest makers of industrial robots in the world. Many robots, including the M-1iA Delta Robot, work in assembly lines to increase the production time of a product. As human beings, we use hand-eye coordination in order to complete tasks on an assembly line. Robots are very precise and their vision, powerful motors (actuators) and lightweight arms can work more efficiently than a human. Today it is more likely for a worker to be trained how to program and function a robot to work on an assembly line rather than completing the task themselves.

WHAT IS A ROBOT?

Social Robots

Scientists have been studying human facial expressions for many years. With the dozens of muscles found in our faces we are able to communicate emotional cues such as joy, anger, or shock. Social robots like EMYS have the ability to detect emotional cues from human beings. Social robots can also be used as a comfort mechanism. Paro is a baby seal used for therapeutic purposes and can have a calming effect on a person in a nursing home or hospital. This idea is much like live Animal-Assisted Therapy. Even though emotional cues can be detected, these robots do not feel or experience emotions themselves.

Telerobotics

Some robots can be controlled from great distances, such as from Earth to Mars! The Curiosity rover is a remotely operated robot on Mars driven by a team engineers at NASA's Jet Propulsion Laboratory on Earth. Every morning the rover is sent a specific list of tasks to accomplish—these tasks include taking pictures of the Martian surface or collecting soil samples. Not all remote-controlled robots have to be millions of miles away; the Da Vinci Surgical System is a robot that assists in making major surgeries minimally invasive. Its robotic arms carefully perform the surgery on the body as the surgeon orchestrates every movement, incision and suture from the Da Vinci console. This console produces a three-dimensional, high-resolution image for the surgeon to observe and manipulate while performing the surgery.

Mobile Robots

GOAL! Soccer 'bots are autonomous robots that move around and play a game of soccer. The robots move with the help of artificial intelligence (AI) software and two cameras mounted above that act as eyes to control the game. These eyes sense and compute data, which then flows to a central computer that holds the AI software. The AI software processes and plans out a strategy for the robots. Finally, the AI software sends out commands to the player 'bots, allowing them to act in the game by kicking or blocking the ball. Mobile robots can be fun, but can also have a more serious purposes: RHex has the ability to travel through rocks, sand, and other climates. This robot is used to study areas that humans are not able to reach or that are unsafe to travel. Attaching objects like climate sensors allow RHex to collect data for humans to study later.

WARM UP

1. Ask students to draw a robot, based upon their experiences.

2. Have students take two minutes to do a "think, pair, share and explain" about what they drew and why they drew their robot in that particular manner.

3. Lead students through a group discussion with an outcome of creating a definition of robots. Pose questions such as:

- Have you ever seen a robot before? What did it look like?
- What type of task was the robot trying to accomplish?
- Does a robot move? Or have arms that move?
- Are robots important? Why?
- What is a robot? Robots use different kinds of sensors to collect the information they need. Software processes this information so the robot can plan a response. Then they act to complete the task.

WHAT IS A ROBOT?

ACTIVITY

1. Assemble students in groups of three to four to work together. Pass out one scenario card and all robot cards to each group.
2. Groups should read through each scenario and pick two robots best suited for the scenario.
3. Pair two groups together to present their scenario to each other. What two robots did they choose and why?
4. Pass out the Robot Comparison student worksheet and have students compare and contrast their original robot drawing from the warm up to the robots they chose to help in a real life scenario.
   - What is similar about the robots?
   - What is different about the robots?
   - If you were to go back and create another drawing would you make any changes? Why?
5. Conclude with a group discussion by sharing their answers from the Venn diagrams and discuss the questions below.

CHECK FOR UNDERSTANDING

- How do you know if something is a robot?
- What is the purpose of a robot?
- What should an engineer take into consideration before building a robot?
- Is a dishwasher a robot? Why or why not?
- Is a cellphone a robot? Why or why not?

WHAT'S HAPPENING?

Students are preparing to visit *Robot Revolution* by dissolving prior misconceptions and reevaluating their thought process about robotics. Through group discussion, students will design a definition of a robot incorporating the idea that robots sense, plan and act in order to complete a series of tasks. This process of sensing, planning and acting is what distinguishes something as being a robot. Students recall prior interactions with robotics to realize how robots are built with a purpose—"form fits function"—to help humans in their everyday lives. Additionally, by making choices based upon specific, real-world scenarios, students will determine what robots would be helpful for humans day-to-day. Using a Venn diagram, students will compare and contrast the robot they drew in their warm up with the robot they chose for their real-world scenario.

DIFFERENTIATED INSTRUCTION

Have students select their two robots and research the different jobs they assist with and/or perform. Students can create a small presentation about their robots, explaining the research they discovered to back up their personal conclusions.

EXTENSIONS:

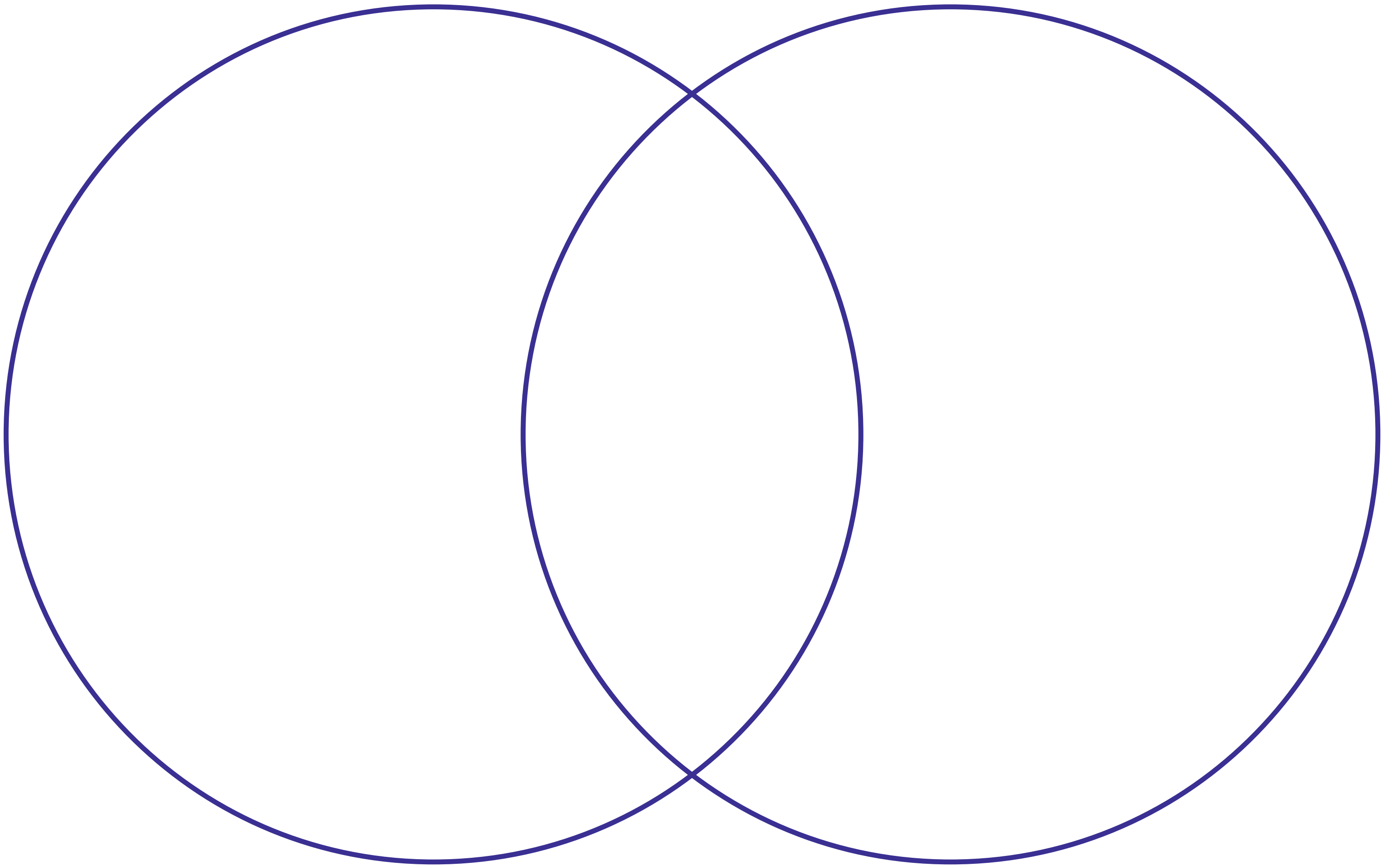
- Have students complete the warm up activity again, and then create a Venn diagram to compare and contrast their two robot drawings.
- Have students complete the warm up again, and then create a 3D-model using classroom materials such as Kleenex boxes, pipe cleaners, construction paper, markers or paper towel tubes.
- Incorporate a read aloud about robots (fiction or non-fiction).

IN THE EXHIBIT:

- PARO
- EMYS
- Baxter
- Da Vinci Surgical System
- Soccer Bots
- Swarm Bots
- RHex
- FANUC M-1iA Delta Robot

ROBOT COMPARISON

NAME: ______________________________ DATE: ______________



ROBOT SCENARIO CARDS

SCENARIO 1

The local hospital wants to make children feel more comfortable after they come out of surgery. Unfortunately, they cannot bring live animals like a dog or a cat to help relax the young patients, but they can bring in robots and different types of artificial intelligence. What type of robot would you offer to the hospital?

- How does the robot work?
- How does your robot benefit the young patients in the hospital?
- Why is this robot the best choice compared to the other robot options?

SCENARIO 2

A new electric car company has just been funded and they are starting to put together their facility where the cars will be produced. The company has hired several employees but they are quickly learning that some of the car parts are too heavy for one person to lift. What type of robot would you offer to assist the electric car company?

- How does the robot work?
- How does your robot benefit the young patients in the hospital?
- Why is this robot the best choice compared to the other robot options?

SCENARIO 3

Scientists are interested in researching rock formations at the Grand Canyon. As they are exploring they discover a cave and have come to a point where humans can no longer fit through the opening. They are curious about the depth of the cave, and if there are any living plant life or insects present. What type of robot would you offer to the scientists to enhance their research?

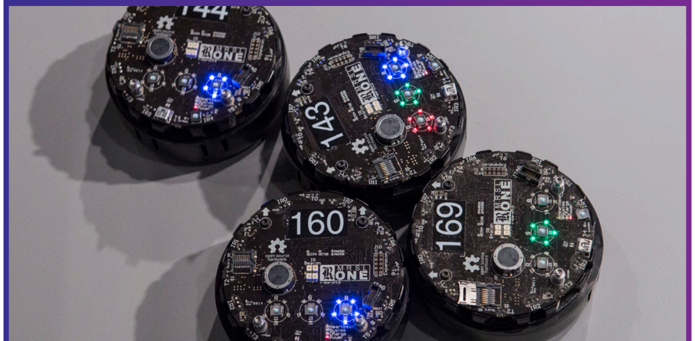
- How does the robot work?
- How does your robot benefit the scientist researching the Grand Canyon?
- Why is this robot the best choice compared to the other robot options?

SCENARIO 4

NASA is interested in learning more about Jupiter's moon Europa. Scientists have discovered that under the icy surface of Europa there is an ocean they would like to research and study. A mission this far into deep space has never been attempted before and NASA is starting to plan for this future event now. What type of robot would you offer NASA to send to the Jupiter's moon Europa?

- How does the robot work?
- How does your robot benefit the young patients in the hospital?
- Why is this robot the best choice compared to the other robot options?

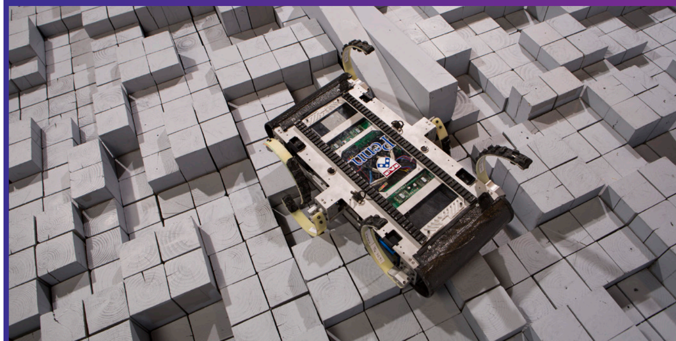
SWARM ROBOTS



Inspired by flocks of birds and swarms of insects in nature, swarm robots work together in groups to operate. Each robot performs its own task, but they all follow one leader in the pack.

These robots are currently in the research phase. Potential future uses include search and rescue, mining and even miniaturization for medicine.

RHEX



RHex has the ability to travel through rocks, sand and other climates. This robot is used to study areas that humans are not able to reach or that are unsafe for travel. Attaching objects like climate sensors allow RHex to collect data for humans to study later.

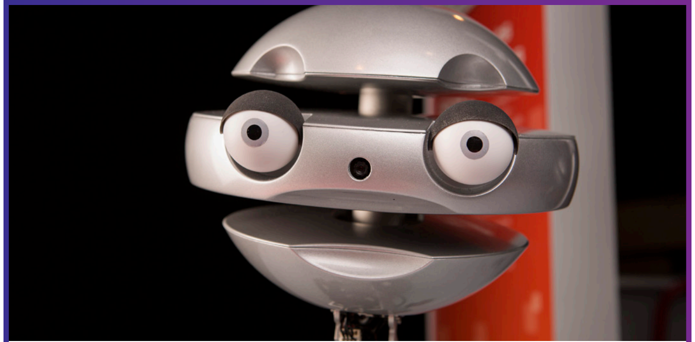
FANUC–M-1iA DELTA ROBOT

The M-1iA Delta Robot works in assembly lines to increase the production time of a product. Humans use hand-eye coordination to complete tasks on an assembly line. Robots are very precise and their vision, powerful motors (actuators) and lightweight arms can work more efficiently than humans. Today it is more likely for a worker to be trained how to program and function a robot to work on an assembly line rather than completing the task themselves.

PARO

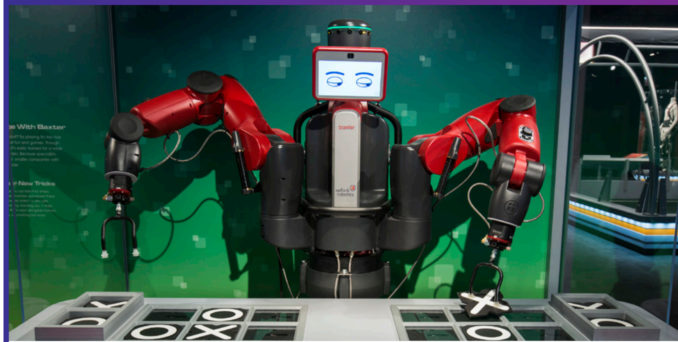
PARO is a therapeutic robotic seal. It is designed to look approachable and to have a calming effect on people who interact with it. PARO works with the help of interactive sensors that allow it to respond when being touched. PARO will respond to petting with reactions such as moving its tail, “purring” and closing its eyes.

EMYS



EMYS stands for "Emotive headY System." It was designed to research how humans react to robots that show emotions. EMYS can show emotions like happiness, sadness, surprise and anger by moving its three disks and two eyes. EMYS can respond to "seeing" a person's face and also responds to touch.

BAXTER



Baxter is a robot that has the ability to "learn." A worker moves Baxter's arms in a desired motion; Baxter memorizes the motions and repeats them over and over. Baxter is often used in industrial environments and is considered unique because it does not need a software engineer to program it.

DA VINCI SURGICAL SYSTEM

The Da Vinci Surgical System is a robot that assists in making major surgeries minimally invasive. Its robotic arms carefully perform the surgery on the body as the surgeon orchestrates every movement, incision and suture from the Da Vinci console. This console produces a three-dimensional, high-resolution image for the surgeon to observe and manipulate while performing the surgery.

ROBOT BRAINS: PROGRAMMING A ROBOT

AT A GLANCE Students will explore the intricacies of robotic programming through an activity where they act as robots and programmers.

OBJECTIVES

Students will:

- Understand how robots complete simple tasks.
- Learn the basics of how programming works.
- Explore how difficult it can be to create a robot that mimics a human.

KEY VOCABULARY

Programming, Computational Thinking

NEXT GENERATION SCIENCE STANDARDS

Science and Engineering Practices:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Constructing explanations and designing solutions
- Obtaining, evaluating and communicating information

Crosscutting Concepts:

- Patterns
- Cause and effect

Disciplinary Core Ideas:

- PS4: Waves and their applications in technologies for information transfer
- ETS1: Engineering design

PACE YOURSELF

- 45 minutes

ADVANCE PREPARATION

1. Gather 12 index cards per team of two students, along with extras for the entire class.
2. Decide how to divide the class into pairs.
3. Create a sample set of programing directions.
4. Prepare a list of example tasks students will need to program their robots to complete.
5. Use the internet to find and print out various types of robotic coding.
6. If classroom computers are available, explore the digital resources to determine which ones would best fit the needs of the class.

MATERIALS

Per student:

- At least 10 index cards (or other small sheets of paper)
- A pencil or pen

WHAT YOU NEED TO KNOW

To complete their tasks, robots have to sense, plan and act. Robots use different kinds of sensors to collect the information they need. Software processes this information so the robot can plan a response. Then they act to get the job done.

Robots need to have someone tell them what to do. This process is referred to as **programming**: the way that we can make robots or computers follow instructions. Any action a robot is going to do needs to be specifically programmed for it to complete the task. A robot "thinks" and learns by processing data and then uses this information to plan its actions.

Programming is the source of instructions for the robot. A robot's program is a set of instructions that tells it what to do, how to do it and when to do it. In order for the robot to complete a task it must be programmed to do so. Programming requires defining a robot's task as a series of logically based step-by-step instructions that can be followed sequentially in order to reach a goal.

A robot's program will also contain a library of simple commands that allow a programmer to describe things in the same way every time. Robots cannot interpret variability in commands the way humans do. For example, a robot will not be able to differentiate between a command to "sit down" versus "please sit."

ROBOT BRAINS: PROGRAMMING A ROBOT

Emphasizing the specificity of the command is important. At times, the robot's environment may be strewn with obstacles or unexpected events. Programmers need to think through the possibilities of these various scenarios and plan accordingly so they can communicate in any situation.

The tasks a robot completes must be defined up front. For example, if the robot does not know how to respond to a command to "sit", then giving the robot that command will result in no action from the robot. A robot will have a library of available actions. Without that action being in its library, the robot is not capable of understanding. One way to think about this is to imagine a programming language that does not have the addition (+) operator that is used in math. In this example, the programmer can never give the computer any math operation that includes addition. Similarly, if the robot does not have a library of actions that says "lift feet," then a programming step that includes "lift feet" will result in the robot doing nothing.

Robot software is the collection of coded commands that tell the robot what tasks to perform. Robot software is used to determine what tasks should be performed and to carry out that action. Programming robots can be an intricate task. Many software systems and frameworks have been proposed to make programming robots easier.

Programming involves computational thinking: a way to analyze and solve problems. **Computational thinking** requires deconstructing the entire decision-making process, the variables involved and all possible solutions, ensuring the right decision is made based on the corresponding parameters and limitations of the problem. Computational thinking can be useful in almost any situation that requires solving a challenge.

WARM UP

Lead students through a discussion about robot programming. Possible questions could include:

- How do people complete a new task they have never done?
- How does the robot know what to do or what types of actions to take?
- In what ways are robots not smart?
- What is holding them back?

ACTIVITY

1. After the discussion, tell they class they are going to explore the idea of robot knowledge and programming.
2. Show the students an example of robotics code. Explain that this is created to tell robots how to complete various tasks. Today they're going to be creating their own programming for human "robots."
3. Divide the class into pairs of students. Explain that one student in each team of two will play the role of the "programmer" and the other will play the role of the "robot." Each robot will be asked to carry out a specific action, such as picking up an object or turning on a computer. The robot cannot carry out any action without being specifically told by the programmer. The student programmers will be programming each of the robots to do specific tasks.
4. Share an example with the students. Read off the programming directions on the prepared example and have a student robot complete the task.
5. Discuss the fact that each step in the programming should be one discrete action, such as walking three steps forward or moving their arm. There should not be more than one action verb in each step.

ROBOT BRAINS: PROGRAMMING A ROBOT

6. Give each of the programming students six index cards and a list of tasks they can program their robot to complete. Examples include moving a book to a different location or throwing away a piece of paper. To prevent the robot students from just naturally completing a task, you may choose to make sure the robot students don't know what the task is that they'll be performing or have the robot students complete the task blindfolded.
7. Ask the programmer to write directions for the robot to complete the task. Each step should be specifically described on an index card, such as move forward six steps. Students do not need to use all six cards if they're not needed.
8. After filling out the cards have the programmer read the directions step by step. The robot should carry out the instructions for each step.
9. Discuss if the teams were able to carry out their task with six steps. Was it hard to think through all the steps before having the robot do them? How many steps were needed to do the tasks? Did everyone do the exact same steps?
10. If the tasks could not be completed, allow students to change their code or use more cards to create additional code.
11. Use the revised cards to try the task again. Did it work better this time? Why or why not?
12. Have the students switch roles with their partner.
13. After everyone has had a chance to write code for their robot, discuss what happened. Was it easy to make the robot do tasks that would be simple for humans? Why or why not? What happened if the code was not written correctly? Discuss how programming is important in robots.
14. Allow students an opportunity to take turns as they program more complex tasks.

CHECK FOR UNDERSTANDING

- Throughout the lesson have students discuss the detailed nature of instructions needed for a robot to perform any task.
- Have students share a time when a computer or other programmed system didn't do what they wanted it to. What are some of the reasons why?
- Ask students to discuss the various things they utilize that have to be programmed.

WHAT'S HAPPENING?

Without step-by-step instructions, the student acting as a robot did not have enough information to complete whatever task he or she was given. This information, referred to as programming, needs to be explicitly given to the robot. In addition, this information has to match against a library of basic actions or steps that the robot can take. This library is key to understanding the limits of a robot's capabilities. Regardless of instructions, the robot cannot operate outside of the limits of this library of actions. If it does not know how to respond to a particular action, it won't be able to complete its task.

DIFFERENTIATED INSTRUCTION

Depending on the class level, students can be given either more complex or less complex tasks to use for programming.

EXTENSIONS

- Complete the activity again with a pre-determined set of robot actions on index cards. In the sample set, show students what happens when they provide an instruction to the robot that the robot is not capable of understanding since it's not in the library. Have students create programmed directions that only have the actions available for that robot.
- Have students do the activity again and create various functions instead of writing out a full line of code. Functions serve as shortcuts, or a way to have a short set of symbols represent a more complex action. These allow programmers to create code without as many lines or information typed out.
- If computers are available, allow students to further explore the basics of coding online using the digital resources.
- Allow students to research more on the history of the Turing test, which was created in 1950 as a way to test a computer's ability to exhibit intelligent behavior. If computers are available, have students use this test with a real chat bot to determine how easy or hard it is for a computer to mimic a human being.

DIGITAL RESOURCES

Free online programming language that makes it easy to create interactive art, stories, simulations and games
http://scratch.mit.edu/

Online community for Scratch educators
http://scratched.gse.harvard.edu/

Computer science non-profit organization
http://code.org/

Online chatbots
http://www.elbot.com/
http://www.cleverbot.com/

Programming-related iPad apps
http://www.daisythedinosaur.com/
https://www.gethopscotch.com/
http://twolivesleft.com/CargoBot/

IN THE EXHIBIT

- Google Self Driving Car
- Programming interactive

ROBOT BODIES: BUILDING A ROBOT HAND

AT A GLANCE Students will learn that robotic "hands," or end effectors, are shaped in different ways depending on their intended function.

OBJECTIVES

Students will:

- Construct a mechanical end effector (a robotic "hand") and test it with a variety of tasks.
- Design a new end effector for a task.

KEY VOCABULARY

End effector

NEXT GENERATION SCIENCE STANDARDS

Science and Engineering Practices:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Constructing explanations and designing solutions
- Obtaining, evaluating and communicating information

Crosscutting Concepts:

- Structure and function
- Systems and system models

Disciplinary Core Ideas:

- ETS1: Engineering design

PACE YOURSELF

- 60 minutes

ADVANCE PREPARATION

Construct an example end effector to use as an example of what the students will be building.

MATERIALS

Per student:

- 5 plastic drinking straws
- 1 sheet of paper
- 1 sheet of cardstock
- Scotch tape
- 1 glue stick
- scissors
- 5 lengths of yarn or string, measured from the arm to the shoulder

WHAT YOU NEED TO KNOW

In robotics, an **end effector** is the part of the robot that interacts with the environment. The three most common types of end effector are mechanical, magnetic and vacuum.

End effectors are designed very differently depending on the task they are intended to perform. Industrial grippers come in many different forms. Some physically grasp the object to be manipulated, like the "hand" the students will build, while others puncture objects with needles, or suck them up with a vacuum, or grip the object with glue. Some use electromagnets to pick up and drop magnetic objects. Effectors can also be tools like drills, screwdrivers or welding torches.

WARM UP

Lead students through a discussion about the types of robots they have seen before. What tasks were those robots intended to perform?

Explain the term "end effectors" (consider showing some of the videos listed in the *Robot Revolution* digital resources). What did the end effectors on those robots look like?

ROBOT BODIES: BUILDING A ROBOT HAND

ACTIVITY

1. Explain that students will build a robotic "hand" that is similar to their own.

2. Have each student trace the outline of their hand on cardstock and paper. Cut out the hands along their outlines.

3. Have students draw lines on their paper hands where their joints are located (use the wrinkles where their fingers bend as a reference).

4. Cut the cardstock hand along the joint lines. You will be cutting each "finger" into three sections. Glue these sections onto the paper hand, making sure you can see the joint lines of the paper hand underneath (you may have to trim your cardstock fingers a little bit). Glue the cardboard "palm" to the paper hand as well.

5. Add "tendons" to allow the hand to bend. Tape a small piece of drinking straw to the lower two joints of each cardboard finger section, with the hole of the straw pointed toward the palm. Make sure both straws are lined up for each "finger."

6. Thread a length of yarn into each "finger" of your hand and tape it in place at the fingertip. When you pull on the other end of the string, the "finger" should bend.

7. Optionally, create a “wrist” by cutting a strip of cardstock 2 inches wide and 8 inches long. Tape the wrist of the paper hand to the center of this strip. Tape five 2-inch lengths of straw to the wrist, and feed the five yarn lengths through these straws. Tape the ends of the card strip together, forming a circle.

8. The hand is complete! Students should be able to bend each finger individually by pulling its string and make the hand grip by pulling all strings together.

9. Have students test their effectors by using them to perform the following tasks:

- Pick up a die and turn it so that the face shows a different number, then put it back down.
- Pick up a heavier object, like a tennis ball or bean bag, transport it to a target one yard away, and put it down again.
- Stack three sheets of paper on top of one another.

CHECK FOR UNDERSTANDING

Ask students to describe their results. Which tasks did their effector perform well? Which tasks did it perform poorly?

Have students select one of the tasks they performed and design a new end effector to perform that task. If time allows, have them construct and test their designs.

WHAT’S HAPPENING?

Students should have noticed that their hand is good at grasping lightweight, three-dimensional objects, but not as good at lifting papers or heavier objects. Ask your students what type of robot might use an effector like the one they built.

DIFFERENTIATED INSTRUCTION

More advanced students may have time to build other end effectors and test them at various tasks.

Students can simulate a vacuum effector by sucking air through a cardboard tube to pick things up. You may want to add a membrane of cellophane punctured by two drinking straws at one end of the tube, to minimize the risk of accidentally swallowing smaller objects.

Students can build a simple example of a magnetic effector using a permanent magnet or a simple electromagnet to sort magnetic and non-magnetic materials.

EXTENSIONS

Mechanical grippers are usually built with two or three “fingers” or prongs, rather than five. Discuss with your students why designers might choose to build robots that look and move similar to humans. What tasks might humanlike robots be better suited for than non-humanoid robots?

DIGITAL RESOURCES

This video shows how to make a simple vacuum effector using a balloon, duct tape, coffee grounds and a vacuum cleaner, and also describes how vacuum grippers work:
https://www.youtube.com/watch?v=3OjhoVuAQkQ
https://www.youtube.com/watch?v=Hb6PajUGXFg

These videos demonstrate how traditional vacuum effectors work:
https://www.youtube.com/watch?v=1F9RT8OjHWE

Here are some good examples of mechanical grippers:
https://www.youtube.com/watch?v=u4ZScJsaepg
https://www.youtube.com/watch?v=EcTL7Hig8h4
https://www.youtube.com/watch?v=4MQmlvzE0i8

And here are some examples of magnetic effectors:
https://www.youtube.com/watch?v=Z8t59j9zjjc
https://www.youtube.com/watch?v=hpyzfm2r-uU

IN THE EXHIBIT

- UR5 Universal Robotic Arm
- Robot grippers

This lesson was inspired by
snapguide.com/guides/make-a-robotic-hand/
tryengineering.org/sites/default/files/lessons/robotarm_0.pdf
www.instructables.com/id/Mechanical-Hand-using-only-fast-food-straws-Stra/

ROBOT SENSES

AT A GLANCE Students will learn that robot sensors can either mimic human sensors or do things that humans cannot. They will use their knowledge to move through an obstacle course, then design a robot to complete a specific task.

OBJECTIVES

Students will:

- Describe the difference between a sense and a sensor.
- Identify human senses and sensors.
- Explain similarities and differences between human senses and robot sensors.
- Choose robot sensors appropriate to a robot's function.
- Make predictions based on observations using tools and their own senses.

KEY VOCABULARY

Sense, Sensor, Robot, Model, Context, Electro-magnetic spectrum, Echolocation, Proprioception

NEXT GENERATION SCIENCE STANDARDS

Science and Engineering Practices:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Constructing explanations and designing solutions
- Engaging in argument from evidence

Crosscutting Concepts:

- Cause and effect
- Scale, proportion and quantity
- Systems and system models

Disciplinary Core Ideas:

- LS1: From molecules to organisms: structures and processes
- PS1: Matter and its interactions
- ETS1: Engineering design
- ETS2: Links among engineering, technology, science and society

PACE YOURSELF

- 45-60 minutes per lesson over two days

ADVANCE PREPARATION

1. Print out robot cards and sensor cards.

2. Arrange the classroom into three aisles of desks.

3. Place objects in the aisles, like chairs or boxes, to act as obstacles. You will move these obstacles throughout the activity, so choose items that are easy to move and safe to bump into. Make the aisles wide enough that students can walk through them with a hula hoop.

MATERIALS

Per class:

- Whiteboard/chalkboard/large paper to write on
- Classroom objects such as chairs, desks, boxes
- 3 blindfolds (could be scarves, eye masks, or other fabric)
- 3 hula hoops
- Printed robot cards and sensor cards
- Cymbal, horn, or other noise-making instrument (optional)
- Timer (optional)

Per student:

- Plain paper
- Pencils

WHAT YOU NEED TO KNOW

We humans are experts at using our senses. A **sense** is a way in which we perceive our surroundings. Humans have a sense of sight, sound, touch, smell, and taste. A **sensor** is a device that detects something; for example, your nose is the sensor you use in your sense of smell.

Robots are machines that can sense, plan, and act. To be a robot, a machine needs sensors. Some of these sensors mimic or enhance human abilities, and some sensors do things that humans can't perceive. Robot sensors allow them to reach beyond human capabilities in order to achieve new tasks, like exploring the surface of Mars or delivering packages across the globe in record time.

When designing and building a robot, engineers often use human and animal models to decide which sensors that robot might need. A **model** is a representation of something that can be used or applied to better understand a concept. For example, engineers designing a sound-detecting robot might use bats as an animal model for echolocation.

ROBOT SENSES

The activities in this lesson compare human sensors to robot sensors. Here is a breakdown of sensors by sense:

TYPES OF ROBOTIC SENSORS:

- Thermometer
- Camera
- Ultrasound
- Thermal Camera
- Gyroscope
- Ultrasound
- Accelerometer
- Microphone
- Pressure sensors: air, water, touch
- Chemical detection (like spectrometers and filters)
- EM wave detection (like RADAR, LIDAR, UV and IR sensors)

Sight

Robots detect vision in ways that are both like and unlike human vision. Some robots have cameras that create images similar to what we see with our eyes. Robots process these images very differently than humans; human brains give context to the images we see, while robot computers process information as objects in space. **Context** is the interrelated information about something that gives it *meaning*. A robot wouldn't know that a chair is a chair; it knows that there are rectangles and squares next to each other in space. Robots can see using sensors that detect waves in the **electromagnetic (EM) spectrum**, the electromagnetic waves that travel through space. Humans can see the part of the EM spectrum known as visible light, i.e. the colors of the rainbow. Robots can detect radio waves, ultraviolet (UV) waves, infrared (IR) waves and more—all of which are outside the range of what humans can see.

Sound

Robot sensors and ears detect EM waves. The sound waves heard with human ears can also be detected by some robot sensors, like microphones. Other robot sensors can detect waves beyond our capabilities, such as ultrasound.

A bird, a falling piano, rain on the roof and a ringing phone all have different meanings to different people. We use sounds both to tell where things are and to tell what those things are. (Fun fact: people with low vision sometimes use clicks to tell where things are around them!) The human brain makes connections between sounds we hear to let us recognize and identify our environment, which robots cannot do yet. Robots can use sound for **echolocation**, locating an object using sound. Robots still have a hard time recognizing the difference between sounds (a bird vs. a plane vs. Superman). This challenge is on the forefront of robotics research.

Touch

Humans use touch to determine features of our surroundings, like temperature, pressure and texture. Robot sensors can sense these same qualities and more. Some robots use sensors to detect objects through contact, like a Roomba. Similar to sight and sound, a robot doesn't necessarily know the content of what they detect (a chair, a slimy banana peel, or Grandma giving you a hug); it knows that there is an obstacle to be avoided or to find.

Smell and taste

Smell and taste, seemingly straightforward senses, are actually very complex and involve a lot of human memory in addition to the sensing actions of the nose and tongue. Neuroscientists are still working to figure out exactly how these complicated senses work. Robot sensors can mimic a nose or tongue by using chemical detection technologies such as spectrometers or other filters that react to certain chemicals (imagine a litmus paper, used inside a robot). These sensors can go beyond human capabilities of smell and taste, since there are some chemicals humans definitely would not want to ingest. Robots don't need to worry about getting sick!

Proprioception: A hidden sense

Proprioception is your body's awareness of where it is in space. When you stand up, your body is able to balance itself and recognize that you are standing. This sense involves multiple sensors, including touch and your body's internal balancing mechanisms. Robots have many sensors that compare to this ability. Gyroscopes and accelerometers detect movement and speed; air pressure sensors and other touch sensors allow robots to position themselves for different tasks. Robots can also detect their exact position in space using sensors like the Global Positioning System (GPS) – something we humans can only do with our smartphones, thanks to robotics!

The activities in this lesson use multiple human senses, focusing mostly on sight, sound, touch and proprioception. Have students identify these senses throughout the lesson, and encourage them to think about how their human sensors compare to those of robots.

WARM UP

1. Ask students to identify human senses and how we use them for different tasks. Define the difference between a sense and a sensor. Make student-generated lists of senses and sensors on the board.
2. Brainstorm and record a list of inventions humans use to enhance our senses (glasses, hearing aids, etc.).
3. Brainstorm with students to define a robot. Be sure to include that a robot senses, plans and acts.
4. Pass out the robot cards. Ask students to identify sensors those robots might use. Do you see a camera? Bumpers? A microphone?
5. Point to a chair in the room and ask the students, what is this? A chair. Ask how they knew it was a chair. They recognized it, they remember being told it's called a chair, they know that a chair is something they sit on etc.
6. Discuss with students that robots can detect objects, sometimes with better accuracy than we can, but they do not attach meaning to objects the way we do. A robot identifies that chair as a series of connecting shapes in space. Ask the students: What shapes make up that chair? Different-sized rectangles.
7. Pass out paper and pencils. Have students draw shapes of objects they see in the classroom. A chair is a bunch of rectangles, a crayon bin is a rectangle with cylinders in it, a water bottle is a long rectangle with a half-circle at the top, etc.

ACTIVITY

Part I:

1. Split the class into three groups.

2. Station each group at one of the three aisles. These aisles are the obstacle courses.
- Ask the class: If I told you to walk down the aisles right now, which senses would you use? Mostly sight.
- Robot sensors don't really see the way we see, so let's take that sense away.

3. Have each group choose one student to be the "robot" who will walk down the course blindfolded. Remind the class that whoever volunteers must be comfortable being blindfolded!

4. Place the blindfold over the volunteers' eyes.

5. Tell the volunteers to walk down the course. Their goal is to avoid any obstacles as they go.
- Ask the volunteers: What senses did you use when you couldn't use sight? Mostly touch.
- Ask the class: Which sensors did you use/observe the robot use? Hands, feet, other parts of the body.
- Robots can use sensors that we humans don't have. Let's add a sensor that might help.

6. Give each volunteer a hula hoop. They can take their blindfold off to put the hula hoop around them, but make sure they cover their eyes again before they go through the course. Tell them they can hold on to the hula hoop to detect when they bump into an obstacle.

7. After the volunteers put their blindfolds back on, have the rest of each group rearrange the obstacles in the courses so the volunteer doesn't know what the course looks like.
- Ask the class to predict how the hula hoop will affect the robot's performance.

8. Tell the volunteers to walk down the course again, this time using the hula hoop to help them.
- Ask the volunteers: How did your sensor help you get through the course?
- Ask the class: What did you observe?
- Ask the class: How do animals find their way in the dark? What is an animal that mostly uses a sense other than sight to maneuver? Bats, fish etc. How do those animals find their way around? Mostly sound.
- Engineers look to animals as well as humans when they design robots. Some sensors use ideas from animals like bats. Let's add another sensor.

9. Have the class come up with three different sounds: one to signal that there is an obstacle in front of the robot, one to signal an obstacle to the left, and one to signal an obstacle to the right. If you have easy access to instruments, you could use cymbals, horns, or other things that make distinct sounds—alternatively, have students use only their voices!
- Make sure these sounds are very different from each other, so the robot can tell the difference between left, right and ahead.

10. Rearrange the objects in each course one more time.
- Ask the class to predict how their sound cues will affect the robot's performance.

11. Instruct the volunteer, blindfolded and with the hula hoop, to go through the course one more time.
- This time, the other students will make sounds to signal the volunteer that they are near an obstacle. If you want, use a timer to track whether the student gets through the course faster than before.
- Ask the volunteers: Was it helpful to have those sound signals?
- Ask the class: How do we use sound? Mostly to identify things around us.

12. Have the students give themselves a round of applause for working together to get their robot through the course! Students can head back to their seats.

Part II:

13. Pass out robot sensor cards.

14. Ask the students to identify which sensors are like human sensors, and which ones aren't.

15. Tell the students that it's time for them to be the engineers. They need to choose sensors for robots to perform certain jobs. Depending on your class, you can have students work in groups of two to three or on their own.

16. Assign the students different jobs for their robots. You may want to write them on slips of paper and pass them out.

- Examples of jobs: analyze rocks on Mars; assemble a toy in a factory; deliver mail to desks in an office; play soccer; lift debris from a beach; drive a car; be a companion for humans; put together a puzzle; climb up a skyscraper; or help someone with low vision or low hearing complete daily activities.

17. Give the students constraints for their choices.

- Tell students they can only choose three sensors.
- Examples of other constraints: budget, weight etc.

18. Have the students write down, report and explain their choices.

CHECK FOR UNDERSTANDING:

Throughout the activites, ask the following questions:

- When you walked through the course the first time, did you recognize objects when you touched them? How did you know the chair was a chair?
- When you had the hula hoop, did you know what an object was when the hoop touched it? Robots can detect obstacles, but do not add context the way humans do.
- When talking about constraints: Was it easier or harder to get through the course when we added the hula hoop? When we added sound? Too many sensors could confuse a robot or make it inefficient, or just be too expensive.

WHAT'S HAPPENING?

Some robot sensors mimic human sensors like eyes, ears and hands. Other robot sensors do things humans can't do like sense infrared light or global positioning. Engineers design robot sensors based on the specific job the robot needs to accomplish.

DIFFERENTIATED INSTRUCTION

- For older or more advanced students, change the constraints in day two to incorporate more math, such as a specific budget or weight allowance. If desired, you can add your own dollar amounts and specific weights to the sensor cards.
- Many of the jobs in day two are examples of robots you'll see in *Robot Revolution*. You are welcome to add anything supporting your current curriculum. For example, if you're doing a weather unit, you might add hurricane prediction or water pollution detection to the list of robot jobs.

ROBOT SENSES

EXTENSIONS

- Open a discussion about uniquely human abilities, like social interaction. Ask students: What combinations of senses do we use to recognize our friend from a stranger? Some senses we take for granted and do really well, like recognizing faces, walking up stairs or knowing how to pick up a dictionary when someone asks for the dictionary. Robots can't do these kinds of tasks well. Some of the robots in the exhibit, like EMYS and PARO, are on the forefront of research to make robots more "like us."
- If you have access to an Xbox Kinect, or a small budget to purchase one for the classroom, you can connect it to a TV screen to show how a robot sees using LIDAR and RADAR sensing technology.
- Have students make videos identifying robot sensors they use in daily life.
- For older students, start a conversation about chemical detection involved in smell and taste. Mass spectroscopy for example is a technology used by the Curiosity rover to analyze chemical properties of Mars rocks and soil.
- Have students walk through the course with just one eye covered to talk about depth perception. Some robots are built with two cameras to act as "eyes."
- Have a discussion about careers that involve not just robot sensors, but human sensors and senses as well. This can be a tie-in to health careers and biological and life science careers.

DIGITAL RESOURCES

Computer science non-profit organization
http://code.org/

Science Buddies explanation of infrared (IR) light sensing
http://www.sciencebuddies.org/science-fair-projects/project_ideas/Robotics_p021.shtml#background

NASA animation of how GPS works
http://spaceplace.nasa.gov/gps-pizza/en/

NASA space and robotics activities
http://spaceplace.nasa.gov/gps/en/

Discovery lessons on human senses for younger grades
http://www.discoveryeducation.com/teachers/free-lesson-plans/the-incredible-human-body-the-five-senses.cfm

NASA Space Place activity on making a topographical map of an unknown object
http://spaceplace.nasa.gov/review/topo-bear/topo-bear.pdf

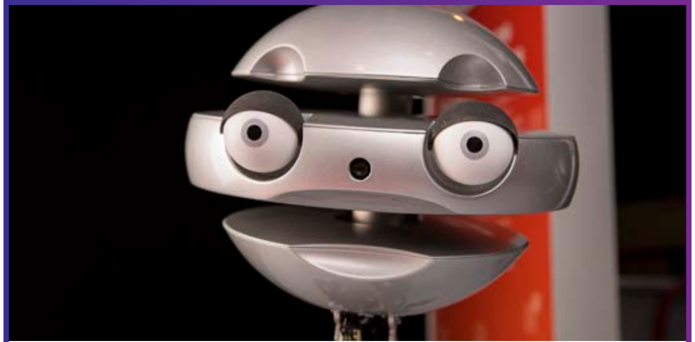
NASA explanation of robots and depth perception
http://spaceplace.nasa.gov/stereo-vision/en/

NASA object identification activity
http://spaceplace.nasa.gov/stereo-vision/en/

IN THE EXHIBIT

- Gripper robots
- Google Self Driving Car
- EMYS: mimics expressions
- UR5 Universal Robotic Arm: proprioception
- ROBOTIS OP: vision tracking, patterns
- PARO: touch sensors

EMYS



EMYS stands for "Emotive headY System." It was designed to research how humans react to robots that show emotions. EMYS can show emotions like happiness, sadness, surprise and anger by moving its three disks and two eyes. EMYS can respond to "seeing" a person's face and also responds to touch.

UNMANNED AERIAL VEHICLE

This robotic vehicle flies without a pilot. It is controlled by people on the ground or pre-programmed with missions before take-off. A drone can sense and respond to its surroundings, such as wind, bad weather, or obstacles in its path.

Drones are used for many jobs, including farming, photography, military surveillance, search and rescue, and supply delivery.

SWARM ROBOTS

Inspired by flocks of birds and swarms of insects in nature, swarm robots work together in groups to operate. Each robot performs its own task, but they all follow one leader in the pack.

These robots are currently in the research phase. Potential future uses include search and rescue, mining and even miniaturization for medicine.

VIDEO CAMERA

Vision sensor most similar to human sight, as it detects the same wavelengths as human eyes. Used to produce images like photographs or moving videos.

Cost: Moderate
Weight: Medium

MICROPHONE

Sound sensor that detects sound signals within the human range of hearing. Used to detect sounds from objects ranging from the very small, like insects, to the very large, like airplanes.

Cost: Moderate
Weight: Medium

TACTILE SENSOR

Pressure sensor that detects physical contact. Can sense a squeeze, but cannot measure weight. Often used in everyday objects, such as keyboards, or to test performance of products, like car brakes.

Cost: Inexpensive
Weight: Light

GYROSCOPE

Movement sensor that detects velocity and orientation. Used inside robots to measure balance. Allows a robot to correct its own movement to stabilize itself.

Cost: Inexpensive
Weight: Light

THERMAL CAMERA (INFRARED)

Detects light wavelengths outside the range of human vision and creates an image on a screen. Often used to detect temperature differences. Can also be used for night vision.

Cost: Expensive
Weight: Medium

LIDAR

Measures distance, shape and speed of objects by bouncing a laser off an object and analyzing the reflected light. Often used to make high-resolution maps.

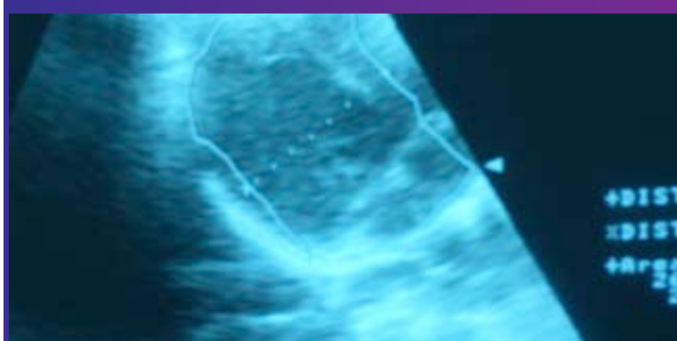
Cost: Expensive
Weight: Medium

INFRARED THERMOMETER

Uses a laser to detect temperatures from a distance. Sometimes accuracy can be affected by surrounding objects. Often used to measure temperatures of moving objects, objects out of reach, or objects too hot or too cold to touch.

Cost: Inexpensive
Weight: Medium

ULTRASOUND DETECTOR



Senses sound wavelengths higher than the range of human hearing. Used to detect objects and measure distances. Can detect a wide area from a single point. Used in medicine, underwater exploration (called Sonar), materials science and more.

Cost: Inexpensive
Weight: Light-Medium

MASS SPECTROMETER

Uses a laser to measure the mass of atoms and molecules. Can identify substances, such as rocks or metals, by separating individual elements and compounds.

Cost: Expensive
Weight: Heavy

GLOBAL POSITIONING SYSTEM

Detects exact location by determining its own distance from satellites orbiting Earth. Often used to track devices and objects, such as in cars and smartphones.

Cost: Moderate
Weight: Light

MAKE YOUR OWN SENSOR

Description:

Cost:
Weight:

MAKE YOUR OWN SENSOR

Description:

Cost:
Weight:

ROBOTS AND SOCIETY

AT A GLANCE After visiting the *Robot Revolution* exhibit, this lesson will have students thinking like engineers and learning about societal impacts on robot development.

OBJECTIVES

Students will:

- Discover how technology and society influence each other.
- Utilize engineering design practices to develop a robot that solves a societal issue.

KEY VOCABULARY

Robot, Roboticist, Effector, End Effector, Sensor, Mechanism

NEXT GENERATION SCIENCE STANDARDS

Science and Engineering Practices:

- Asking questions and defining problems
- Constructing explanations and designing solutions
- Obtaining, evaluating and communicating information

PACE YOURSELF

- 60 minutes

ADVANCE PREPARATION

1. Place students in teams of three or four and be able to work at one table together.
2. Print the Robot Mechanisms Cards (one set of nine cards for each group).
3. Print the Societal Scenario Cards so each group has one scenario. There are four scenarios, so with eight groups, for example, two groups should have the same scenario.
4. Print the Roboticist Design Worksheet (one sheet for each group).
5. Print the Robot Student Worksheet (one per student).
6. At the start of class, each group should have nine Robot Mechanisms Cards per group and a Robot Student Worksheet for each student.

MATERIALS

Per group:

- 9 Robot Mechanism Cards
- 1 Societal Scenario Card
- 1 Roboticist Design Worksheet
- Sensor cards from Robot Senses lesson (optional)

Per student:

- Robot Student Worksheet

WHAT YOU NEED TO KNOW

To complete their tasks, robots have to sense, plan and act. **Robots** use different kinds of sensors to collect the information they need. Software processes this information so the robot can plan a response. Then they act to get the job done. Some robots are programmed in advance to do certain tasks, while others can actually adjust certain parameters of their own programming to respond to things that happen to them. For example, a drone can keep hovering at a given height whether it's being buffeted by wind or swatted by a person. The drone, like other robots, is in a constant loop of sense, plan and act as long as it's turned on.

Robots are made for a variety of purposes and to serve different people. One type of robot, a drone, has many applications, from delivering food, medicine and packages to surveying and keeping track of wildlife to use in warfare. Depending on your background, values and cultural upbringing you may perceive robots differently. Some robots being produced today are being designed to look like humans; others look like machines but have human characteristics, and some you may not realize are robots until you look a little closer.

ROBOTS AND SOCIETY

Roboticists use the engineering design process to design and make robots. Many times these robots are designed to suit some need within a society or used for research purposes within a university to suit a particular topic of interest. Either way their experiences shape the way they design robots.

In this lesson, students will pick **mechanisms**, or mechanical parts, for a personal robot and then use the engineering design process to make a robot that suits a particular societal want or need. The mechanisms they will be selecting from fall into three categories: end effectors, sensors and movement.

In robotics, an **effector** is a part of the robot that interacts with its environment and an **end effector** includes all the devices that can be installed at a robot's wrist. The most common end effectors are grippers (to learn more about end effectors see the Robot Bodies lesson). A **sensor** is a device that detects something; for example, your nose is the sensor you use in your sense of smell (to learn more about sensors and senses see the Robot Senses lesson).

WARM UP

Lead students through a discussion about robots and robot mechanisms they discovered in the *Robot Revolution* exhibit. Possible questions could include:

- What robot did you like the most and why?
- What features or mechanisms of the robots did you find most interesting and why?
- What are some ways in which robots can help people?

ACTIVITY

1. Have each student in the group look at the nine Robot Mechanism Cards to learn about different features their robot can have and let them pick four mechanisms for a personal robot. Each student in the group can pick whatever four mechanisms they want even if another student has picked the same ones.

2. List on their Robot Student Worksheet the four robot mechanisms they selected and explain why they chose them.

3. Ask some students to share with the class what mechanisms they picked for their own personal robot and why.

4. Ask the students if they would change any of their choices after hearing some of their classmate's choices and reasons. Explain that this is part of the engineering design process and working as a team to come up with the best possible design.

5. Give each group a Societal Scenario Card and a Roboticist Design Worksheet and have the group work together to design a robot that addresses the societal want or need on the card.

6. Explain that engineers start with a problem that can be solved through developing or designing a solution. Roboticists are engineers that work exclusively with robots.

7. Record on the Roboticist Design Worksheet what problem they were given and then discuss and write down the mechanisms the robot should have. Students can use the mechanisms cards from the first section, be given additional sensor cards from the Robot Senses lesson and/or come up with their own. There is no limit to the number of choices students can make in this section.

8. After they have made their choices as a group they will sketch out their design, making sure to add all the mechanisms they have selected.

9. All groups will present their problem and designs to the class.

10. As students are presenting, act as the client for each scenario. Ask questions about why they chose certain mechanisms and help them really think about their choices by asking questions like "Have you considered……?" or "What if ……. happens?" etc.
11. Allow students to make changes to their initial design based on feedback given and their own thoughts as they watched the other groups present.
12. Have them answer the remaining questions on page two of the Robot Student Worksheet.

CHECK FOR UNDERSTANDING:

- Why were your personal choices different than the choices you made for your societal problem?
- How might who we are or where we live influence what robots are made in the future?
- Do you think engineers usually work in teams to design solutions? Why or why not?

WHAT'S HAPPENING?

In having students compare their personal choices to choices they would make given a particular societal issue they need to solve, they can make the connection about how technology and society are intertwined.

Using creativity and teamwork to design and redesign a robot allows students to practice the skills of an engineer. Presenting their designs allows them to practice communication skills.

DIFFERENTIATED INSTRUCTION

Depending on the level of the class or students, you can make the engineering design process more or less challenging. Give every group the same societal problem to work on instead of different problems. To make it more challenging, have the groups come up with their own societal problem to address.

EXTENSIONS

This lesson can be incorporated into a longer engineering design curriculum. Students can go through every step of the engineering design process by starting with the problem, designing a robot to solve the problem, building a prototype and/or testing some of their ideas, then redesigning, rebuilding and testing again.

This lesson also can be combined with history or social studies by having students research different cultures or historical problems and incorporate their findings into their robot design.

DIGITAL RESOURCES

Videos and articles about robotics, including their impact on society.
http://www.ted.com/topics/robots

List of robots that have been or are being developed
http://robot-kingdom.com/

Lesson plans on nanoscience, which is related to robots
http://www.nisenet.org/search/product_category/k-lesson-plans-15

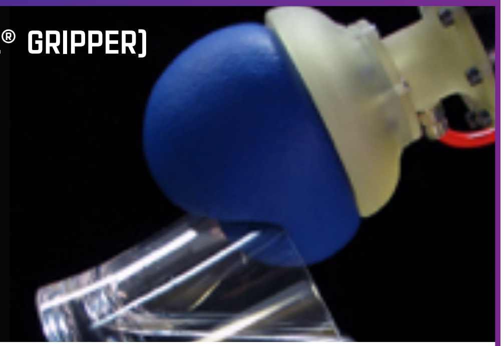
This lesson was inspired by
www.nisenet.org/catalog/programs/exploring_nano_society_-_you_decide

IN THE EXHIBIT

- VERSABALL® Gripper
- Robotiq 3-Finger Adaptive Robot Gripper
- PARO Therapeutic Robot
- ROBOTIS OP
- Drone
- Double Telepresence Robot

VACUUM END EFFECTOR

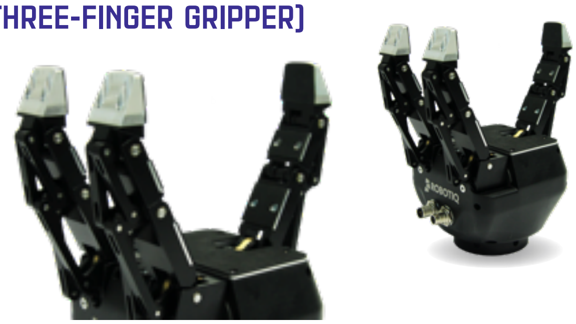
(VERSABALL® GRIPPER)



Vacuum end effectors like the one above have a granular material like coffee grounds or sand inside and use a vacuum to wrap around an object and then pick it up. They can pick up delicate objects like an egg without breaking them. However, they cannot pick up really large objects or very tiny objects and are limited in how much they can move the object around once it is picked up.

MECHANICAL END EFFECTOR

(THREE-FINGER GRIPPER)

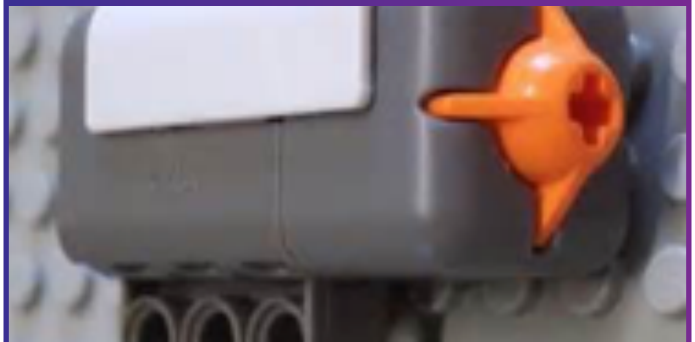


Mechanical end effectors, like this three-finger gripper, grip objects similar to how a person would. This allows for more movement of the object once it is picked up. However, they are not able to pick up objects of every shape and will likely crush very delicate objects like an egg.

MAGNETIC END EFFECTOR

Magnetic end effectors use a powerful magnet or magnets to pick up or move objects. They can pick up an object of almost any size or shape, but the object they want to pick up needs to be magnetic for it to work.

TOUCH SENSOR



Touch sensors detect pressure. When the sensor is pushed or bumps into something, the robot can programmed to respond in many ways. For example, the PARO robot in *Robot Revolution* has many touch sensors under its fur. PARO is programmed to respond with noises and movement depending on how soft or hard it is touched. Touch sensors are often used on grippers so the gripper knows when to squeeze and when to release.

VISUAL SENSOR

There are many types of visual sensors from ones that just detect light and dark to ones that detect UV or infrared light to specialized cameras. A visual sensor can be used in combination with programming for security, allowing the robot to respond to lights going on and off; for designing a robot that can follow a path; for giving a robot the ability to learn faces and respond to different people; for taking pictures or video automatically; or for reacting to any type of visual signal.

SOUND SENSOR

There are many types of sound sensors. Some detect how loud or soft a sound is, while others can recognize details of people's voices. In combination with programming, sound sensors can be used to type or write what you are saying; to understand speech and respond to you; to react to music or any other sound.

WHEELS

Wheels allow a robot to move around quickly and in all directions. They are easier to make and program, but are limited to use on mostly flat surfaces.

LEGS

Two, four, six or more legs give a robot movement similar to humans or animals. Legs are hard to make and complicated to program. Currently most robots with legs move slowly and fall down easily. Some can climb stairs and some can go over obstacles, but most only work on flat surfaces.

PROPELLERS

Propellers allow a robot to zip through the water or fly through the air. They can be damaged by running into an obstacle.

SOCIETAL SCENARIO CARDS

A large corporation sells and ships items all over the world. They sell items as small as a ring to as big as a car. They can get many items to their customers in as quickly as 24 hours, but would like have packages delivered in less than 12 hours. These packages sometimes need to get across oceans or mountains and must be delivered directly to people's homes or businesses.

A small country is constantly threatened by earthquakes. Recently a 7.8 magnitude earthquake hit the country, killing hundreds of people and destroying many homes and businesses. The country's leaders would like a robot or robots that can search through rubble to find survivors, help with the clean up and rebuild structures to get the country back on its feet.

Farms all over the world are attacked by bugs, small mammals and birds that feed on the crops. Many farmers don't want to kill these animals, but would prefer if they found their food somewhere else. They would like a robot or robots to help; these robots can be any size, but cannot interfere with the farmers when they are harvesting their crops.

SOCIETAL SCENARIO CARDS

An elderly woman with no children is starting to have trouble getting around her house. She is starting to forget to take her medicine and needs help preparing her meals. She wants to be able to stay living at home, but is going to need help. The robot needs to be able to easily move around her house, help with everyday chores and give her reminders.

ROBOTICIST DESIGN WORKSHEET

NAME: ______________________________ **DATE:** ______________________

Write the problem you are trying to solve from your group's Societal Scenario Card.

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Work together to describe the size of your robot or robots:

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____

Work together to describe how you will power your robot or robots:

____

____

____

List mechanisms the robot or robots will have (there are no limits to the number of mechanisms):

____

____

Draw your robot in the box below and label all the mechanisms.

STUDENT WORKSHEET

NAME: ______________________________ **DATE:** ______________________________

List four mechanisms you would want in a robot for yourself and explain why you chose them.

MECHANISM 1:	**WHY:**
MECHANISM 2:	**WHY:**
MECHANISM 3:	**WHY:**
MECHANISM 4:	**WHY:**

Do you think your choices are the same as your classmates? Why or why not?

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STUDENT WORKSHEET

NAME: ______________________________ **DATE:** ______________________

What changes did you make to your design after your presentation?

Do you think it was good to make changes? Why or why not?

How might a robot designed in another country be different than a robot designed in the United States?

List three other problems you think a robot might be able to help solve and explain how.

1) ____

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____

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2) ____

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3) ____

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ROBOT REVOLUTION EXHIBIT GUIDE

» FOCUSING YOUR FIELD TRIP

AT A GLANCE Students will record their observations and experiences in the *Robot Revolution* exhibit and complete a follow-up writing exercise in the classroom. development. and learning about societal impacts on robot development.

OBJECTIVES

Students will:

- Have a meaningful museum experience.
- Connect their museum experience to the classroom.
- Learn what robots are and what they can do.

KEY VOCABULARY

Observation

NEXT GENERATION SCIENCE STANDARDS

Science and Engineering Practices:

- Constructing Explanations and Designing Solutions
- Obtaining, Evaluating and Communicating Information

PACE YOURSELF

- 30 minutes in the classroom before your field trip
- 30 minutes in the exhibit during your field trip
- 30 minutes in the classroom after your field trip

ADVANCE PREPARATION

Print a *Robot Revolution* Exhibit Guide worksheet for each student.
Print and assemble an extra one to uses as an example for students.
Print copies of the My Robot worksheet to use after the field trip.

MATERIALS

Per group:

- Copy of *Robot Revolution* Exhibit Guide
- Copy of My Robot worksheet
- Pencil
- Markers or crayons (optional)

Per student:

- Stapler
- Scissors

WARM UP

Complete the "What is a Robot?" lesson. This is optional, but recommended.

Briefly define observation. It involves using all five senses to receive information from the outside world. Making observations is an important part of science.

ACTIVITY

In the classroom before your field trip

1. Tell students they will record their observations, experiences and thoughts while they explore the *Robot Revolution* exhibit. They will make observations in the exhibit to better understand what robots are. They will then use their observations to design their own robot after their field trip.
2. Show them an example of an assembled *Robot Revolution* Exhibit Guide. Briefly read each page and discuss what they will do in the exhibit.
3. Pass out materials and give them time to assemble their exhibit guides. Cut on the dotted lines and staple the pages together with two staples, like a book. Be sure to staple the pages together in numerical order.

ROBOT REVOLUTION EXHIBIT GUIDE

In the exhibit during your field trip

1. Ensure each student has their *Robot Revolution* Exhibit Guide and a pencil. Consider giving each chaperone an Exhibit Guide and having them fill it out as well.

2. Walk around with students as they explore the exhibit. Make sure they are recording their observations and experiences on each page. If they need more room, they can use the back of each page. Encourage students to not only record what they see and learn, but to also what they feel and experience.

3. When everyone has explored the exhibit, collect their pencils and Exhibit Guides to make sure they are not lost or dropped in the museum.

In the classroom after your field trip

1. Give each student their *Robot Revolution* Exhibit Guide and the My Robot worksheet.

2. Tell students to use their observations noted in their Exhibit Guide to design their own robot on the My Robot worksheet. They will first determine what their robot will be used for, i.e., its purpose. Encourage them to create a robot that performs a specific job which improves the way they live, work, or play. For example, have them think of a robot that could help them get ready for school faster.

3. Have students fill out the My Robot worksheet, drawing their robot and answering questions to determine how it works. They can even color their drawing.

CHECK FOR UNDERSTANDING

- What is the purpose of this robot?
- It what ways is this robot similar to or different than humans? What can it do that humans cannot?
- How does this robot sense, plan, and act?
- How can this robot make our lives better?

WHAT'S HAPPENING?

Making **observations** is a central component of science and the scientific method. It involves receiving information from the outside world through the senses and recording information using scientific instruments.

DIFFERENTIATED INSTRUCTION

Tell students the purpose of their robot before they create it. For example, they must create a robot that can deliver food and water to people after a natural disaster.

Have students describe their finished robot to each other and to the class.

ROBOT REVOLUTION
Supported by Google.org

EXHIBIT GUIDE

1

NAME: ____

Instructions: Cut pages, assemble in numerical order and staple to form a booklet.

COOPERATION

2

Robots work with humans and other robots to make our lives better.

Find a robot and describe what it is doing.

____

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How could it work with humans to make our lives better?

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____

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SMARTS

3

Robots are "smart" because they process internal and external information that guides their actions.

Draw and describe a robot that seems to be "smart."

SENSE

4

All robots gather information with **sensors**, such as microphones, lights and cameras.

Draw a robot and label its **sensors**.

SKILLS

5

Robots have different “hands” depending on what they are designed to do.

Find a robot “hand” and draw it.

How is it different than your hand?

PLAN

6

All robots process information to **plan** their actions.

Experiment with a robot that **plans** and draw it.

What is the robot’s job or purpose?

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LOCOMOTION

7

Draw and explain one way a robot can move around.

Robots move in different ways, and they can go places humans can’t.

ACT

8

All robots **act**, such as move or speak.

Make a robot **act**. What is its job or purpose?

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What can it do that humans cannot do?

____

____

MY ROBOT

NAME: ______________________________

Use the information you gathered in the exhibit to create your own robot.

Here is a picture of MY ROBOT:

The purpose of MY ROBOT is to. . .

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MY ROBOT has sensors that can. . .

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MY ROBOT is "smart" because it can. . .

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MY ROBOT can do things humans can't do:

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