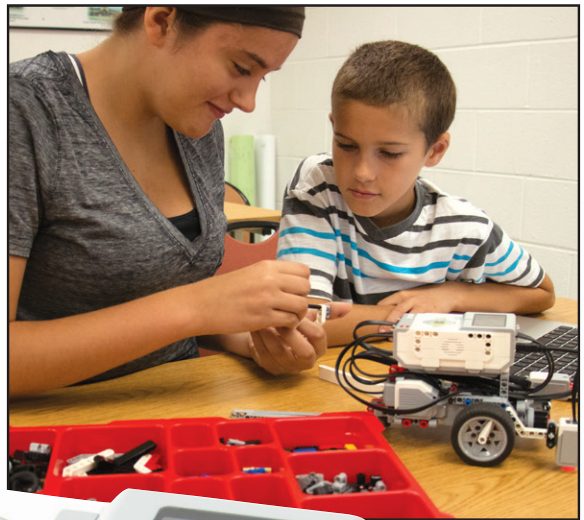
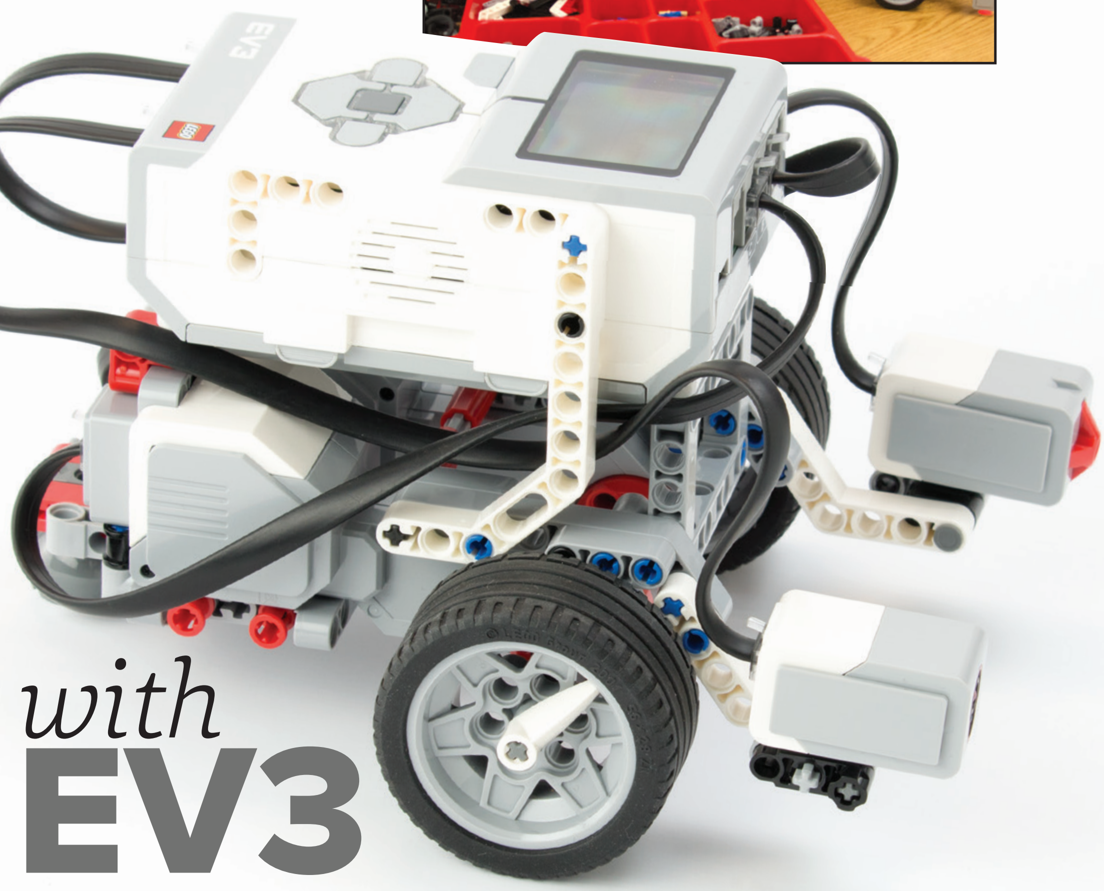
OHIO STATE UNIVERSITY EXTENSION

4-H 507



ROBOTICS 1 *with* EV3



Name ________________________________

Age ________________________________

(As of January 1 of the current year)

Club name ________________________________

Club advisor ________________________________

County ________________________________

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

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NATIONAL PEER REVIEWED

This project book demonstrates adherence to the highest educational standards within 4-H.

The videos that accompany this project were created by TRECA Creative Services. Special thanks to Jeff Davidson, Josh Ebert and Matt Lanzoff for their media support and expertise.

2/17—6.5M—XXXXXX

Contents

NOTES TO THE PROJECT HELPER

Congratulations! A 4-H member has asked you to serve as a project helper. You may be a parent, relative, project leader, friend, club advisor, or another person important in the 4-H member's life. Your duties begin with helping the youth create and carry out a project plan, as outlined in the Member Project Guide. This is followed by helping the youth focus on each activity, providing support and feedback, and determining what was done well, what could have been done differently, and where to go next.

As a project helper, it is up to you to encourage, guide, and assist the 4-H member. How you choose to be involved helps to shape the 4-H member's life skills and knowledge of the importance of robotics.

Your Role as Project Helper

Your contributions are critical to delivery of the 4-H program, which is committed to providing experiences that strengthen a young person's sense of belonging, generosity, independence, and mastery. It is essential that your interactions support positive youth development within the framework of these Eight Key Elements:

1. Positive relationship with a caring adult
2. Welcoming environment
3. Opportunity to value and practice service
4. Opportunity for mastery
5. Physically and emotionally safe environment
6. Opportunity for self-determination
7. Engagement in learning
8. Opportunity for self-determination

For more information on the Eight Key Elements, please refer to the Advisor Handbook available online at **ohio4h.org**. On a practical level, your role as a project helper means you will . . .

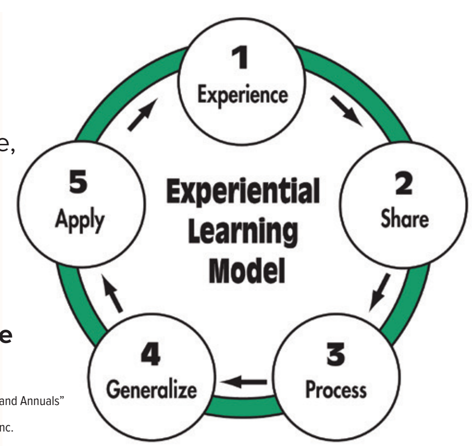
- Guide the youth and provide support in setting goals and completing this project.
- Encourage the youth to apply knowledge from this project book.
- Serve as a resource person.
- Encourage the youth to go beyond the scope of this 4-H project book to learn more about robotics.

What You Can Do

- Review the Learning Outcomes (project skill, life skill, educational standard, and success indicator) for each activity to understand the learning taking place. See the inside back cover for the Summary of Learning Outcomes.
- Become familiar with each activity and the related background information. Stay ahead of the learner by trying out activities beforehand.
- Begin the project by helping the learner establish a plan. This is accomplished by reviewing the Member Project Guide.
- After each activity or project area is completed, conduct a debriefing session that allows the learner to answer the review questions and share results. This important step improves understanding from an experiential learning perspective.
- Help the learner celebrate what was done well and to see what could be done differently. Allow the learner to become better at assessing his or her own work.
- In the Member Project Guide, date and initial the activities that have been completed.

What You Should Know About Experiential Learning

The information and activities in this book are arranged in a unique, experiential fashion (see model). In this way, a youth is introduced to a particular practice, idea, or piece of information through an opening (1) **experience**. The results of the activity are recorded on the accompanying pages. The member then (2) **shares** what he or she did with the project helper and (3) **processes** the experience through a series of questions that allow him or her to (4) **generalize** and (5) **apply** the new knowledge and skill.



Pfeiffer J.W., & Jones, J.E., "Reference Guide to Handbooks and Annuals"

Member Project Guide

Welcome to the exciting world of robotics! In this project, you'll learn what a robot is, how to build one using a LEGO® MINDSTORMS® robotics kit, and how to program a LEGO® robot to interact with its environment. All activities are based on the LEGO® EV3 system.

Robotics 1, which is appropriate for all age levels, is designed to be completed as an individual project, although many 4-H members complete their individual projects while working together in a small group, sharing knowledge and skills as they go. No previous knowledge of robotics is required, but younger members should take this project under the direction of a knowledgeable adult. The project can easily be completed in one year. Members who want to continue in robotics are encouraged to move on to *Robotics 2: EV3N More*.

Check your county's project guidelines (if any) for completion requirements in addition to the ones below, especially if you plan to participate in county project judging or plan to prepare an exhibit for the fair.

PROJECT GUIDELINES

Step 1: Complete **all twelve** activities and **all** of the Talking It Over questions.

Step 2: Take part in **at least two** learning experiences.

Step 3: Become involved in **at least two** leadership/citizenship activities.

Step 4: Complete a project review.

STEP 1:

Project Activities

Complete **all twelve** activities and **all** the Talking It Over questions. The More Challenges activities are optional. As you finish activities, review your work with your project helper. Then ask your project helper to initial and date your accomplishment.

ACTIVITY	DATE COMPLETED	PROJECT HELPER INITIALS
PROJECT AREA: THE BASICS		
1. What Is a Robot?		
2. What's What		
3. If I Only Had a Brain		
Talking It Over		
PROJECT AREA: BUILDING YOUR FIRST ROBOT		
4. Start with Something Simple		
5. Let's Get a Move On		
6. One Step at a Time		
Talking It Over		
PROJECT AREA: SENSORS		
7. Let's Be Sensible		
8. I've Got a Feeling!		
9. Do You See What I See?		
10. All the Pretty Colors		
11. Two Sensors are Better Than One		
Talking It Over		
PROJECT AREA: WHAT DO YOU WANT YOUR ROBOT TO DO?		
12. Small Tasks, Big Accomplishments		
Talking It Over		

STEP 2:

Learning Experiences

Learning experiences are meant to complement project activities, providing the opportunity for you to do more in subject areas that interest you. What are some learning experiences you could do to show the interesting things you are learning about? Here are some ideas:

- Attend a clinic, workshop, demonstration or speech related to robotics.
- Help organize a club meeting based on this project.
- Go on a related field trip or tour.
- Prepare your own demonstration, illustrated talk, or project exhibit.
- Participate in county judging.
- Attend or participate in a robotics competition.

Once you have a few ideas, record them here. Complete at least two learning experiences. Then, describe what you did in more detail. Ask your project helper to date and initial in the appropriate spaces below.

PLAN TO DO	WHAT I DID	DATE COMPLETED	PROJECT HELPER INITIALS
Demonstration	*Showed club members the basic contents of a LEGO® Mindstorms EV3 kit.*	*4/5/YR*	*T.D.*

STEP 3:

Leadership and Citizenship Activities

Choose at least two leadership/citizenship activities from the list below (or create your own) and write them in the table below. Record your progress by asking your project helper to initial next to the date each one is completed. You may add to or change these activities at any time. Here are some examples of leadership/citizenship activities:

- Teach someone about programming a robot.
- Help another member prepare for his or her project judging.
- Help organize a club field trip to a science museum or to a manufacturing plant that has robots.
- Encourage someone to enroll in Robotics 1 with EV3.
- Arrange for someone from a local manufacturing firm to speak to your club about robotics.
- Plan your own leadership/citizenship activity.

LEARNING/CITIZENSHIP ACTIVITIES	DATE COMPLETED	PROJECT HELPER INITIALS
Taught club member how to make my robot purr like a cat.	*5/5/YR*	*T.D.*

STEP 4:
Project Review

All finished? Congratulations! After you've completed the activities in this book you are ready for a project review. This process will help assess your personal growth and evaluate what you have learned.

Use the space below to write a brief summary of your project experience. Be sure to include a statement about the skills you have learned and how they may be valuable to you in the future.

Now...

set up a project evaluation. You can do this with your project helper, club leader, or another knowledgeable adult. It can be part of a club evaluation or it can be part of your county's project judging.

1 What Is a Robot?

The words **robot** and **robotics** are used to describe many things, some of which are actually robots and some of which aren't. To successfully use robots, you need to understand what they are and what they can do.

Words in **bold** throughout this book are defined in the glossary.

WHAT TO DO

The Robotic Industries Association (RIA) defines a robot "a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks."

Wow! Those are some big words. Let's see if we can simplify it a bit. Robots are much more than mere machines. But what, exactly, are they?

The following list serves as a good, basic description. A robot must . . .

- **be programmable.** A robot must have some type of instructions that can be changed by the operator.
- **be automatic.** A robot must be able to work without a person controlling it.
- **be a multi-use machine.** A robot must be able to do different jobs either by changing the program or by changing the parts.
- **sense its surroundings.** A robot must have sensors that are used to collect information about its environment.

Use the checklist next to each item below and on the top of the next page to determine whether it is a robot.

Gas Pump

- ○ programmable
- ○ automatic
- ○ multi-use
- ○ senses surroundings

Is it a robot?

○ yes ○ no

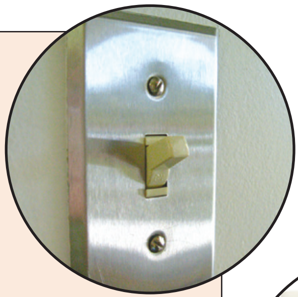
Blender

- ○ programmable
- ○ automatic
- ○ multi-use
- ○ senses surroundings

Is it a robot?

○ yes ○ no

Light Switch



- ○ programmable
- ○ automatic
- ○ multi-use
- ○ senses surroundings

Is it a robot?

○ yes ○ no

Washing Machine

- ○ programmable
- ○ automatic
- ○ multi-use
- ○ senses surroundings

Is it a robot?

○ yes ○ no

Answers are on page 40.

MORE CHALLENGES

- *Make a list of toys that are based on robotics. Explain to your project leader or two other club members how the toys meet the definition of a robot.*
- *Create a timeline of the history of robots. Use it for your project display at the fair.*

LEARNING OUTCOMES

Project skill: Identifying machines a robot or not a robot

Life skill: Understanding systems

Educational standard: NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved

Success indicator: Identifies machines as robots or not robots

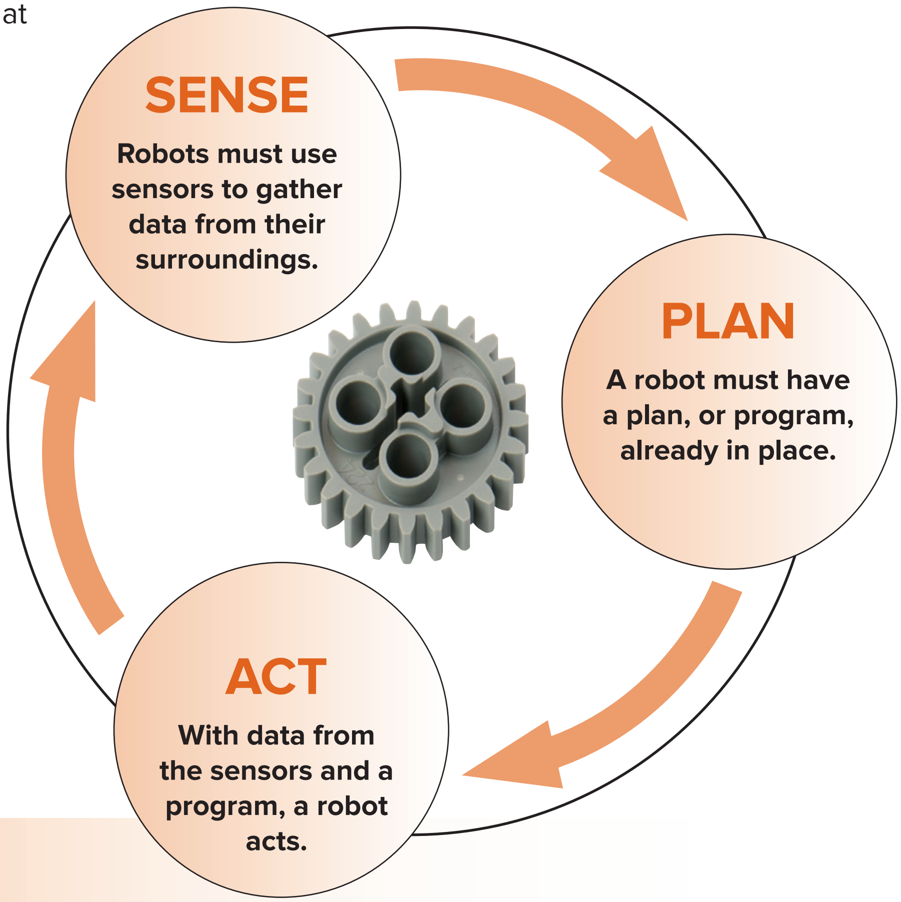
BACKGROUND

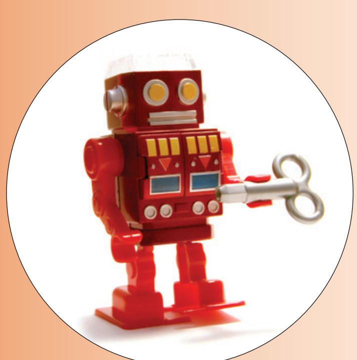
"I can't define a robot, I just know when I see one."

—Joseph Engelberger, the "Father of Robotics"

Think about the tools and machines you hear about and use every day. Can you relate to the quote above? Defining what a robot is can be challenging; scientists and engineers have been debating the topic for decades. A key part of the definition is that a robot must sense its surroundings. We'll explore this later.

Robotic technology is used in many places, including medicine, manufacturing, space programs, and even the military. From robots that help build new cars to ones that allow surgeons to perform surgery through a tiny hole in a patient's skin, it is clear that robots play an increasingly important role in our lives.





www.freeimages.com

Did you know?

The word robot was first used in 1920 in R.U.R. (Rossum's Universal Robots), a book of science fiction by writer Karel Capek.

What's What

Robots can be made from many different parts and materials. This project uses the LEGO® system, mainly because LEGO® parts are readily available and easy to use. Just like any technical subject, this one has its own vocabulary. Let's take a moment to be sure that for the rest of this project, we are speaking the same language!

WHAT TO DO

Write the letter of the image that matches each part's description.

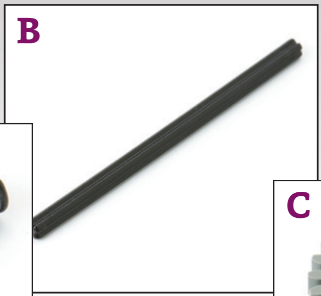
1. _____ **Frames** are a new LEGO® part that are rectangular and help you easily create more stable builds.

2. _____ The **ball caster** is a ball mounted inside a plastic socket. When built, this can act as an omni-directional wheel—a wheel that can roll in any direction—for your robot designs.

3. _____ The large **servo motor** is a powerful motor that gives motion to your robot. By using the built-in rotation sensor, the motor can align with other motors on the robot so that it can drive in a straight line. The motor design also makes it easier to create gear trains.

4. _____ A **TECHNIC beam** is the basic building element in the EV3 robotics kit. A TECHNIC beam has no studs and an odd number (1, 3, 5, 7, etc.) of holes in the side. TECHNIC beams come in various lengths and are measured by the number of holes they have. This TECHNIC beam is a "7."

A



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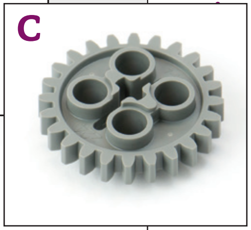

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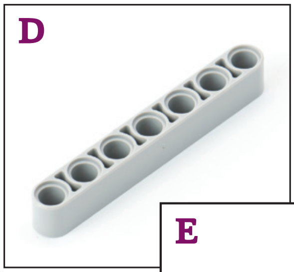

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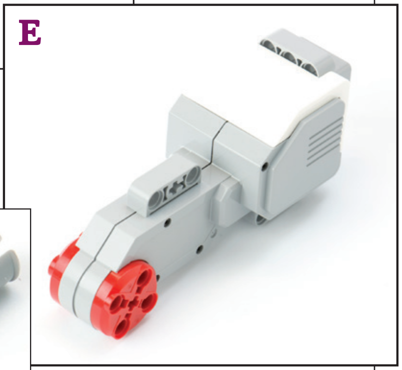

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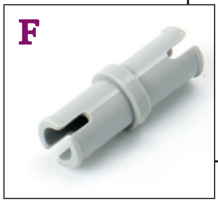

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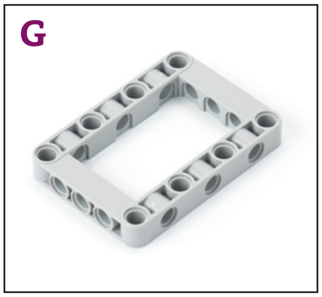


G

H

––List continues on next page––

5. _____ **Gears** are used to transfer movement from one part of a LEGO® model to another part of the model. Gears come in many sizes and are described by the number of "teeth" they have. In your robotics kit, the smallest gear is an 8-tooth and the largest is a 40-tooth gear. This gear is a 24-tooth gear.

6. _____ An **axle** is a small rod that is used with a wheel or a gear to turn the wheel or the gear. An axle looks like a plus sign (+) from the end. Most axles are black or gray in color. Axles are also measured in stud/hole length. To determine the length of an axle, use a TECHNIC beam to measure it.

7. _____ This type of **TECHNIC connector peg** is black and has small ribs on it that make it more difficult for the peg to turn inside the hole of a beam due to friction. Connector pegs (also called pins) are used to connect TECHNIC beams and other LEGO® parts. In the EV3 set, most of the structure is held together with these elements.

8. _____ This type of **TECHNIC connector peg** is gray, and is smooth so the peg can turn freely inside the hole of a beam to create a movable connection.

Answers are on page 40.

Now that you are familiar with the LEGO® EV3 parts, open your LEGO® EV3 kit and sort all of your parts into the compartments. LEGO® provides a sorting guide that shows you where each kind of part goes. If you do not have the sorting guide, one is available at **ohio4h.org/robotics**.

If you always use this sorting guide it will be much easier for you to find the parts you are looking for when you need them later in the project.

Record the date you sorted your parts here:

____

LEARNING OUTCOMES

Project skill: Identifying and describing the function of LEGO® robotics parts

Life skill: Understanding systems

Educational standard: NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved

Success indicator: Matches image of part to its name and definition

MORE CHALLENGES

Experiment with different ways to connect your LEGO® parts and make sketches or take pictures of your discoveries.

BACKGROUND

Engineering is an ancient field of human science. Early humans used their knowledge of the natural world to figure out things such as how to irrigate crops and how to build boats that would stay afloat.

The term engineer comes from the Latin word "ingeniator," meaning one with ingenium, the ingenious one. Leonardo da Vinci had the official title of Ingegnere Generale. His notebooks reveal that some Renaissance engineers began to ask systematically what works and why.

Over time, as humans learned more about science and mathematics, engineering became more complex. The field of engineering paved the way for the modern technological society we live in.

As you work through this project, you are exploring the field of robotics engineering. As an engineer, you must constantly be asking the questions why and how. Why did my robot do that? Why didn't that work like I thought it would? How could this work better? Asking these questions will allow you to get the most learning and enjoyment out of your robotics project.

Did you know?

The name "Mindstorms" comes from the title of a book written in 1980 by Seymour Papert, a computer scientist at the Massachusetts Institute of Technology (MIT). Papert wanted to train children in computer programming. He argued that it may be one of the most promising ways to teach children about the nature of problem solving.

RESOURCES

Find out what engineers do and what it takes to become an engineer at **futuresinengineering.org**. Here's even more about engineering and engineering careers: **tryengineering.com**.

3 If I Only Had a Brain

Before you go any further, you need to test your EV3 intelligent brick by writing, downloading and running a simple program. The EV3 intelligent brick is the large white and gray brick with the screen and buttons. It doesn't really look like a LEGO® brick does it?

WHAT TO DO

Using the instructions that came in your EV3 robotics kit, install the EV3 software on your computer. EV3 software is usually downloaded from the LEGO® Education website using an activation code. If you need help with this, ask a parent or project helper.

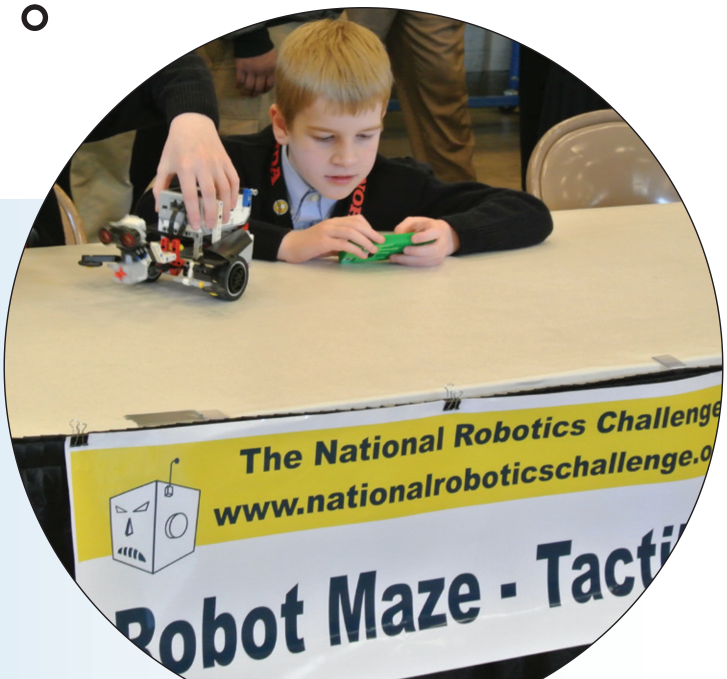
After the software is installed, go to **ohio4h.org/robotics** and watch the video called Activity 3: If I Only Had a Brain. Try programming your brick with another sound. Can you make it bark or growl like a dog? How about not just once, but in a loop?

TECH TIP

It may take a few more minutes, but watching the videos once before trying the instructions is a big help.

MORE CHALLENGES

To learn more about programming go to code.org to try your hand at some simple computer programming puzzles.



LEARNING OUTCOMES

Project skill: Installing and using programming software

Life skill: Processing information

Educational standard: NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved

Success indicator: Installs and programs intelligent brick software

BACKGROUND

The LEGO® EV3 intelligent brick is no ordinary LEGO® brick. It is the microprocessor, or the "brain" of your robot and is actually a small computer. It has a screen so you can see what is going on, and buttons you can use to give instructions. This is really what makes your kit a robot rather than a machine.

An example of a robot from everyday life is a digital video recorder, or DVR. Read the descriptions below and think about how the program, input, and output are used by a DVR to record a television show.

Program

The program, also known as the "algorithm" or "code," is the robot's set of instructions. In this case, you are programming (or instructing) the DVR to record your favorite television show for one hour.

Input

When you use the remote control to program your DVR, you send input through infrared signals that tell the DVR it's time to perform a certain task.

Output

Finally, look at the output, or the action you want the robot to take. Here, the action is to turn the DVR on at the start of the hour, and off at the end of the hour. You can see certain lights come on to indicate that the DVR is taking action. The control loop is complete as the DVR records your favorite show.

Did you know?

The first general digital computer was completed in 1945 and was called ENIAC. It filled an entire room and weighed more than 60,000 pounds.

RESOURCE

Here is Intel's handy collection of 35 interactive, online lessons for learning about technology, computers, and society: **educate.intel.com/en/TheJourneyInside**. Click on Explore the Curriculum.

Talking It Over

SHARE Using your own words, define the word robot.

REFLECT Why is defining a robot so difficult?

GENERALIZE When you are learning something new, is it easiest for you to imitate what you see in a demonstration (like the video) or would you rather experiment on your own and discover an answer through trial and error? Explain.

APPLY Name at least one other task that is easier to accomplish with some planning and organization. Include an explanation of the planning and organizing that is required.

Start with Something Simple

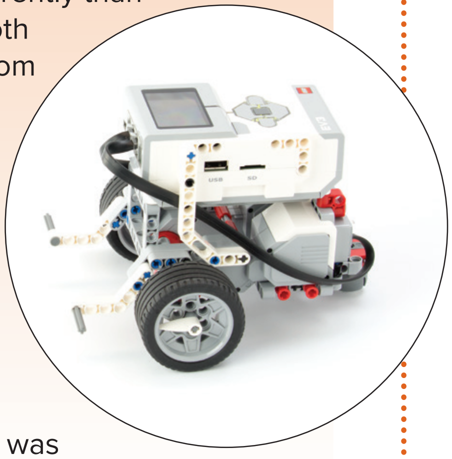
4

Now you are ready to build your first robot! For now, let's keep things simple and build the robot from the parts included in your basic EV3 kit. After you complete this first robot, you can experiment with ones that are more complicated.

WHAT TO DO

Before building, go to **ohio4h.org/robotics** and watch the video called Activity 4: Start with Something Simple.

Step-by-step instructions for building the **driving base** are included with the LEGO® MINDSTORMS Education EV3 Software and on printed directions that come with your kit. The steps in the software instructions may be numbered differently than the steps in the printed directions, but that's all right. They are both picture guides to building the driving base. If you want to work from printed instructions and no longer have your booklet, they are also available on **ohio4h.org/robotics**.



Don't forget to familiarize yourself with the basic operation of the brick.

Record the date you built the driving base here:

____

When you're finished, answer these questions.

What was the hardest part about building the driving base? What was the easiest part?

____

____

How did having your parts organized help you to follow the directions?

____

____

Give at least one example of things people keep organized so that they can find them when needed.

____

____

Following instructions, especially technical ones, can be difficult. What advice would you give to someone who is about to build his or her first robot?

____

____

TECH TIP

In the instruction booklet that comes with the kit, the ratio "1:1," which is read as "one-to-one," means the picture of the piece is exactly the same size as the actual piece. With lots of similar pieces, these 1:1 pictures really help! You can easily check if you have the right part by laying it on top of the drawing.

A helpful feature of the LEGO® EV3 brick is the brick status light that surrounds the brick's buttons. Brick status light codes are as follows:

- *Red = Startup, Updating, Shutdown*
- *Red pulsing = Busy*
- *Orange = Alert, Ready*
- *Orange pulsing = Alert, Running*
- *Green = Ready*
- *Green pulsing = Running Program*

You can program the brick status light to show different colors and to pulse when different conditions are met. Learn more in the EV3 Software Help or in the User Guide in the Quick Start window. The User Guide contains lots of helpful information, so don't be afraid to refer to it if you're having trouble.

MORE CHALLENGES

A robot that needs to move around is often called a rover. Rovers are designed to operate on specific types of surfaces, such as sandy, rocky, muddy, or smooth. Do some research. Where are rovers used?

LEARNING OUTCOMES

Project skill: Building a robot

Life skill: Processing information

Educational standard: NGSS MS. ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved

Success indicator: Builds driving base for a basic EV3 robot

BACKGROUND

The robot and its parts are called the **hardware** of the system. The EV3 programming application is **software**. Software can perform many different, specific tasks, while hardware can only perform the mechanical tasks it is designed for.

- **Operating system software** refers to a computer's operating system, or OS. Operating software is what makes your computer hardware work. It is usually already installed on a computer when you buy it. The most common OS software are Windows, Mac OS X, and Linux. Computer software includes the operating system, device drivers, diagnostic tools, and more.
- **Application software** are programs added to the OS to allow users to complete tasks. Examples are browsing the internet, writing a text document, or drawing a picture. Application software are programs you must install by yourself.
- **Programming software** helps programmers write more software. Think of the programming software as a translator. It helps you communicate what you want to the computer and its hardware. Programming software is written in a special language that the computer understands. Like application software, programming software is installed by the user.

Firmware is the computer code that translates your commands between the hardware (the EV3 brick) and the software. Sometimes you may need to update your EV3's firmware. To do that, click on the "Tool" menu and select "Firmware Update."

Updating the firmware on your brick will clear its memory, so you'll have to download all of your projects and programs again. Make sure you've saved everything!

Did you know?

Each LEGO® **brick** must be manufactured within one-thousandth of a millimeter of the designed specifications or the bricks will not stay firmly connected.

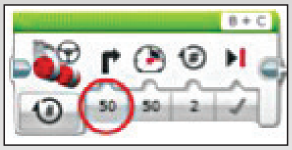
5 Let's Get a Move On

Now that you have built your robot, you have to program it. As you know, a robot is a combination of hardware (the parts) and software (the program). Hardware and software are important and must work together for the robot to function. If you are good at designing and building but you do not understand programming, your new robot won't be much fun. To be a successful robotics expert, you have to understand both pieces of the robotic puzzle.

WHAT TO DO

To learn how to create a basic EV3 program for your new robot, go to **ohio4h.org/robotics** and watch the video called Activity 5: Let's Get a Move On.

After you run your first program, change the settings for the first "move steering" block as indicated below and answer the questions. When you're running the same program multiple times, instead of selecting it from the file folder tab, try selecting it from the first tab. That tab is called the "run recent" tab, and it will keep a list of programs you have run the most recently. Save yourself some time and run your programs from here.



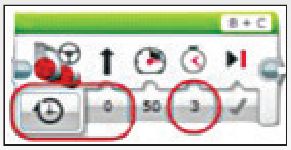
What do you think will happen when you push the run button?

____

____

Try it! What happened?

____



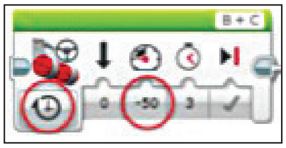
What do you think will happen when you push the run button?

____

____

Try it! What happened?

____



What do you think will happen when you push the run button?

____

____

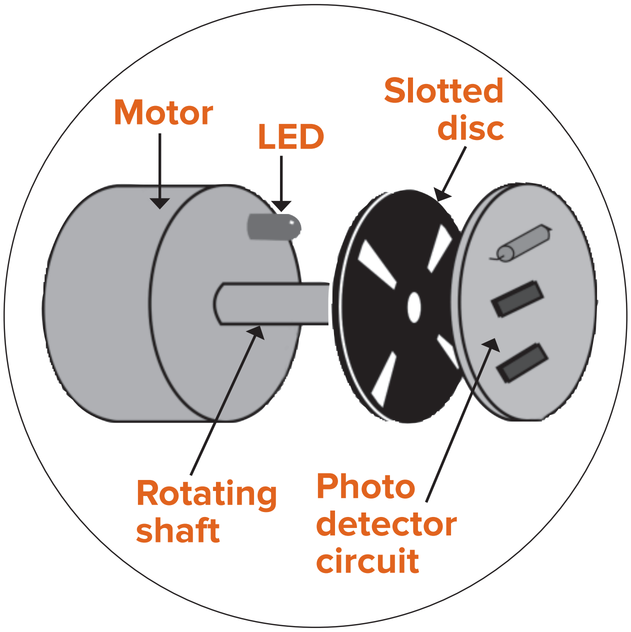
Try it! What happened?

____

Having trouble? Robots follow commands very specifically. In each command block in your program, there is a spot in the upper right corner that shows which port is receiving the command. Make sure that your cables are connecting the correct ports to the correct parts. For example, in this activity, ports B and C control the large motors, so make sure the large motor cables are connected to those ports.

BACKGROUND

In the program, you specified to have the motor turn for a certain number of rotations. So how does the robot "know" how far the motor has turned? It relies on a device called an **encoder**. The most common encoder is called an optical encoder. Inside the EV3 motor housing are three basic components: a light source (usually a light emitting diode or LED), a slotted disc, and a photo detector circuit. A single encoder is shown in the diagram. As the motor turns the slotted disc, the light from the LED shines through the slots in the disc. The photo detector circuit picks up the light and sends a signal to the EV3 robot so that it can keep track of the rotations of the motor.



MORE CHALLENGES

Experiment with moving the steering control to the left or right. Create some notes so that you know what each position of the slider makes the robot do.

TECH TIP

These videos were made using an Apple computer. If you are using a PC, your screen will be slightly different. For example, the "Save as" has a different pop-up box. No worries—they both work the same way!

LEARNING OUTCOMES

Project skill: Writing a program that enables your robot to move forward

Life skill: Planning and organizing

Educational standard: NGSS MS. ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success

Success indicator: Programs robot to follow commands and move forward

Did you know?

LEGO® EV3 motor encoders read to an accuracy of one degree of rotation. This is called the **resolution** of the encoder. With a resolution of one degree, the encoder cannot make sense of, for example, 66.5 degrees.

6 One Step at a Time

You have built a robot and have learned how to program it to move forward and backward. Now that your robot is mobile, it must be able to follow a route or a path. This is done by writing multiple, **sequential** commands for the robot to follow. The process is kind of like following a recipe.

If you give the robot the wrong instructions or if the instructions are in the wrong order, the robot does not perform as expected.

WHAT TO DO

To learn how to create a simple route program for your robot, go to **ohio4h.org/robotics**, and watch Activity 6: One Step at a Time.

Run the new program. Did your robot do what you expected? Explain.

____

____

Change the ***duration*** of the turn in the program (the second move steering block) to “0.5.” Download the program to your robot and run this new program. What does your robot do now?

____

____

Using your new skills, create a short course in your house for your robot and create a program that drives your robot through it. For example, guide your robot from one room to another or around two table legs.

____

____

How long did it take to get the program to work? ____________________

If you run the program four times in a row, does the robot always end in exactly the same spot? Why do you think this happens?

____

____

“Once you have a route or a path program in place, you can count on your robot to run it successfully.”

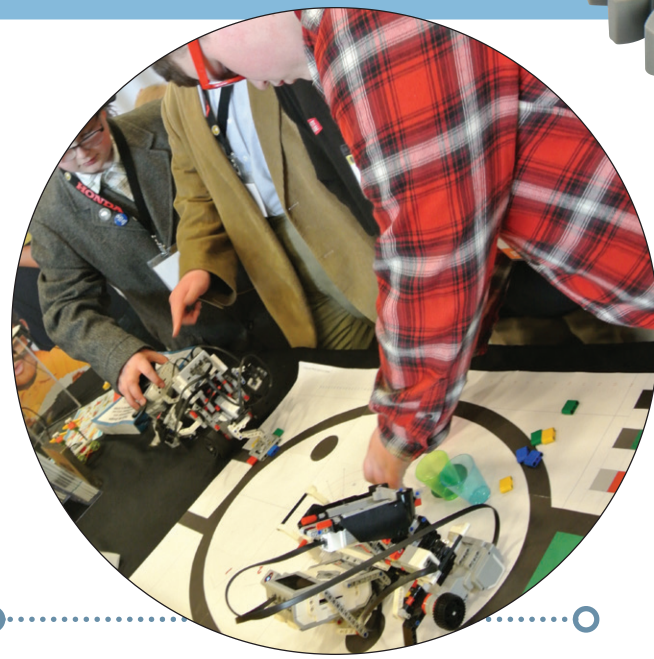
Do you agree with this statement? Why or why not?

____

____

MORE CHALLENGES

Program your robot to follow a course that another member of your family defines. Is it easier to program your own path or to program one that someone else gives you?



BACKGROUND

With patience and determination, you should have been able to get your robot through the course you made. It's not quite as easy as it looks! Your robot probably did not end at the same spot every time. Why didn't it?

There are two possible reasons. First, if you don't start the robot in exactly the same place at the beginning of each run, it will not end in the same spot either. The second reason is **friction**. As the robot moves, the parts move, and anytime something moves there is friction. Friction is the scientific term for two things rubbing against each other. This rubbing—or friction—causes the robot to move a little differently every time the program is run.

Did you know?

NASA has two robotic rovers exploring the surface of the planet Mars. They were named Spirit and Opportunity by a third grader who won an essay contest.

LEARNING OUTCOMES

Project skill: Writing a program that enables your robot to follow a path

Life skill: Planning and organizing

Educational standard: NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved

Success indicator: Programs robot to follow a specified route to completion

TECH TIP

If your EV3 brick suddenly stops working and cannot be shut down through the normal process, you will need to reset it. Resetting does not delete existing files and projects from previous sessions in the EV3 brick memory. However, files and projects from the existing session may be lost.

1. *Make sure that the EV3 brick is turned on.*
2. *Hold down the back, center, and left buttons on the EV3 brick.*
3. *When the screen goes blank, release the back button.*
4. *When the screen says "Starting," release the center and left buttons.*

Talking It Over

SHARE Did the robot usually operate as you expected after you changed the program? Explain why or why not.

REFLECT When a robot behaves in an unexpected way, what has really happened?

GENERALIZE Do you agree with the statement: “Computers do only what people tell them to do?” Explain?

APPLY Name another task (besides baking a cake) in which the order of the tasks is extremely important. Now, name one in which the order of the tasks is not important.

Let's Be Sensible

Adding sensors can help your robot overcome the challenges of friction or obstacles. **Sensors** give your robot a way to "sense" its environment. Just as your five senses give you the ability to adjust your actions, sensors allow your robot to do the same.

WHAT TO DO

Identify the sensors in your kit. Write the letter of the image that matches each sensor's description.

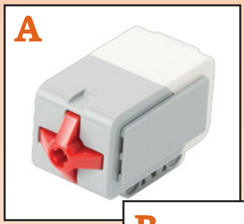
1._____ With the color sensor, your robot can tell the difference between colors. This sensor also lets you program your robot to determine the brightness of a room, or the amount of light an object reflects.

2. ____ The touch sensor gives your robot the ability to "feel" its way through its environment. By creating attachments for your robot's touch sensor, you can make your robot react when it runs into obstacles.

3. ____ The ultrasonic sensor gives your robot depth perception, or the ability to judge the distance of objects.

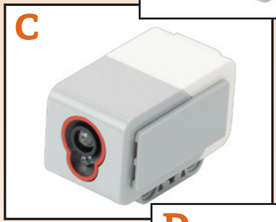
4. ____ The gyro sensor detects rotation on a single axis. If you rotate the gyro sensor in the direction of the arrows on the sensor, the sensor can detect the rate of rotation in degrees per second. You can use this sensor to detect when your robot is turning, or when it's falling over.

A



B

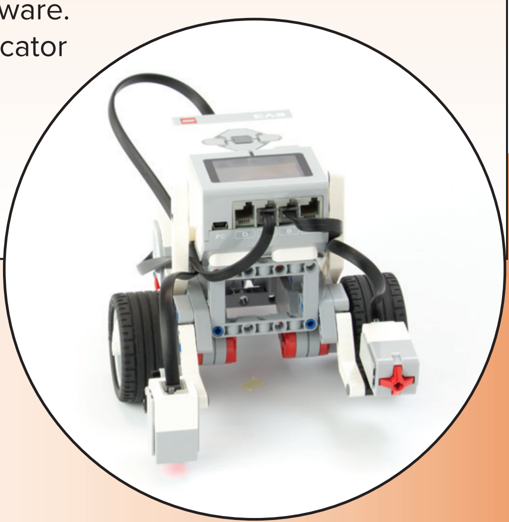
C



D

Now that you know what each sensor does, attach the touch sensor to your robot. You can learn how with the building instructions in the Mindstorms Education EV3 Software. Click on the Building Instructions in the Robot Educator section of the lobby, then select Touch Sensor—Driving Base. You can also view them online at **ohio4h.org/robotics**.

––What to Do continues on next page––



Answers are on page 40.

LEARNING OUTCOMES

Project skill: Identifying hardware functions

Life skill: Processing information

Educational standard: NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved

Success indicator: Identifies the function of each sensor

When you are finished, answer these questions.

In what ways are the sensors on your robot similar to your own senses? In what ways are they different?

____

How will sensors add to the tasks that your robot is capable of doing? Give at least two examples.

____

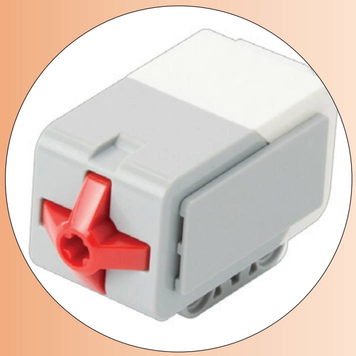
BACKGROUND

Now your robot has a touch sensor! So, what do you use it for? Touch sensors are often used in robotics to help robots know when they're running into something. In robotics, it is very important that your robot and everyone around it is safe.

Let's say you have a robotic lawn mower. While your robot is mowing, your dog decides to take a nap in the middle of the yard. When your handy little mowing robot runs into the dog, it has to "know" to change direction; otherwise, your dog might get an unwanted haircut! A touch sensor, sometimes called a bump sensor, allows the robot to know that something is in the way. In robotics, this is called **obstacle detection**. To avoid accidents, all robots that drive around in crowded places must have some type of obstacle detection system.

MORE CHALLENGES

Make a sketch of a robot that you might want to invent someday. Label all of the sensors that your robot will need, and write a paragraph describing how your robot will work.



Did you know?

A touch sensor is basically an electric switch. Just like a light switch in your house, it can either be on (pushed) or off (released).

I've Got a Feeling!

Now that the sensor is attached, your robot needs a program so that it knows how to use the sensor and knows how to react to its surroundings.

Make sure the touch sensor cable is plugged into port 1, and the large motor cables are plugged into ports B and C.

WHAT TO DO

To create your new program, go to **ohio4h.org/robotics** and watch the video called Activity 8: I've Got a Feeling! Create and run your new program.

When you are finished, answer these questions.

Describe what your robot did when you ran the program.

____

____

What are some other things that might keep your touch sensor from working as planned?

____

____

Describe another program you could write that uses the touch sensor.

____

____

MORE CHALLENGES

Create a new program using the touch sensor so that your EV3 robot makes a loop around your kitchen one time.

LEARNING OUTCOMES

Project skill: Writing a program that enables the robot react to its surroundings

Life skill: Mastering technology

Educational standard: NGSS MS. ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved

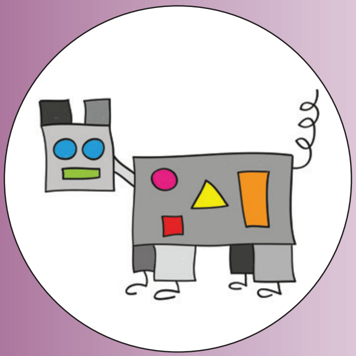
Success indicator: Programs the robot to use its sensor and navigate its surroundings

BACKGROUND

Now you really have a robot. It senses its surroundings with the touch sensor and reacts when it runs into an object by turning around and driving in a different direction.

The next step for developing your robot is to learn how the other sensors in your kit can be used to give your robot more ability to sense. The more "senses" your robot has, the better it's able to make decisions. Think of it this way: When you walk into a dark room, what is the first thing you do? You probably look for the light switch. Why is that? Well, your light sensors (your eyes) need a certain amount of light to work properly. Without light, you are not able to use your eyes to make decisions about your surroundings. When you lose one of your senses, you decision-making ability suffers. The less input you have, the harder it is to make a good plan for your actions.

Your robot is the same. If you can give your robot access to more sensors, you can create more complex programs and have your robot complete more complex tasks.



www.freeimages.com

Did you know?

What's the difference between an **automaton** and a robot? Usually, the word automaton refers to a machine that looks and moves like a living thing. In the mid-1700s, French engineer Jacques de Vaucanson invented a mechanical duck that ate and digested food!

Do You See What I See?

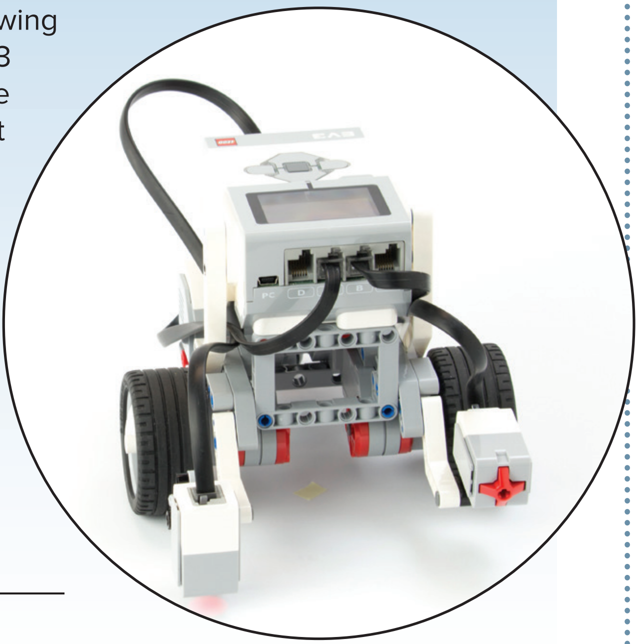
In this activity, your robot gains the ability to "see" light and dark then make decisions about what to do.

Make sure the Touch Sensor cable is connected in port 3, and that the Large Motor cables are connected in ports B and C.

WHAT TO DO

Build the color sensor down attachment by following the instructions in the Mindstorms Education EV3 Software. Click on the Building Instructions in the Robot Educator section of the lobby. Then select Color Sensor Down—Driving Base instructions. They are also available online at **ohio4h.org/robotics**.

Also at **ohio4h.org/robotics**, follow the programming instructions in the video called Activity 9: Do You See What I See. After you have done the programming, answer these questions.



Why do you need a Loop Block and a Switch Block in the line tracking program?

____

____

What does the threshold for the color sensor do?

____

____

In the second program, we used the Move Steering Block instead of the Motor Blocks. Can you explain why?

____

____

What happens when you set the threshold higher and lower? (Try it!)

____

____

BACKGROUND

Repeatability is the robot's ability to behave the same way every time a program runs. The repeated movement is measured over time. Repeatability is key to robot performance. From spot welding to material handling, nearly every application requires it. Repeatability is most important in industries that need very accurate products. Those robots have much higher repeatability than your little EV3 robot. Industrial robots like the Motoman K6 can repeat movements within one-tenth of a millimeter. Wow!

Since your robot does not have great repeatability, it can use sensors instead of motor rotations to track where it goes. Using its sensors to follow a path, your robot can adjust as it runs.

MORE CHALLENGES

Think of other uses for the color sensor besides following a line. List your ideas, pick one, and see if you can design a program that demonstrates your idea.

TECH TIP

How to Make a Line

Your robot needs a line to follow. You can use duct tape or a line that is already built in to your floor. For example, you might be able to use the line between two kinds of flooring in your house, like hardwood and carpet. You can also print a line on your computer, or download one to print out here: ***ohio4h.org/robotics****. Make sure you secure your line to the floor.*

LEARNING OUTCOMES

Project skill: Programming the color sensor

Life skill: Using scientific methods

Educational standard: NGSS 3-5. ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved

Success indicator: Builds and programs the color sensor

Did you know?

The color sensor not only reads reflected light, it can also "see" colors. It cannot recognize a picture, but it can recognize if an object is red, green, blue or yellow.

All the Pretty Colors

Earlier in this book you learned how to use sensors to make your robot follow a black line on the ground. The nice thing about following a line is that you know where you want the robot to go. What if instead you want your robot to make decisions between multiple options based on sensor input? Let's say the robot is mining in a cave and you want the robot to move right if it sees a red sign or left if it sees a green sign.

Before learning how to program a robot to make decisions, you should know that robots only "think" in numbers. The robot can be programmed to make decisions based on numbers, but not based on opinion.

WHAT TO DO

After reading each question below, decide whether it can be answered by a robot, a human, or both:

Which color is darker?	robot	human	both
Where is the warmest place in the room?	robot	human	both
How does sunshine feel?	robot	human	both
Is a painting beautiful?	robot	human	both

You will need to really think about how to program your robot to make decisions based on the colors it sees. Once again, go to the Building Instructions included in your software. This time, complete the Color Sensor Forward—Driving Base. The instructions should be simple—you just need to make sure your color sensor is now facing forward instead of down. Now, follow the instructions for building the Cuboid too. You can also view and download the instructions online at **ohio4h.org/robotics**.

To learn how the color reading feature of the color sensor can help create more complex programs, go to **ohio4h.org/robotics** and follow the instructions in the video called Activity 10: All the Pretty Colors. When you are finished, answer these questions.

Why is selecting the "default case" radio button important?

____

____

What tasks do you envision programming for your robot?

____

____

Do you think it would be useful to be able to program a robot to have opinions and feelings? Explain.

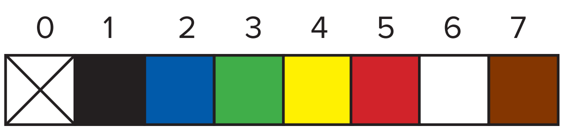
____

____

BACKGROUND

The EV3 color sensor can be used to measure ambient light and light reflected from the red LED on the front of the sensor. It can also distinguish between eight different colors. You can use the features to build color-sorting and line-following robots, or to experiment with light reflection of different colors. By doing so, you will gain experience with a technology that is widely used in industry.

As you know, robots operate by turning information into a mathematical format that the computer processor can work with. With the color sensing feature, each color corresponds to a number. 0 is "no color," black is 1, blue is 2, green is 3, yellow is 4, red is 5, white is 6 and brown is 7. You can use the chart below to help you troubleshoot your sensor if you're unsure why the robot isn't behaving as expected.



TECH TIP

When you test your robot, place the color cube vertically, with your desired color on the top. This will put the color at the same height as the sensor, making it easier for your robot to gather color information.

MORE CHALLENGES

Learn about computer programming language by converting the numbers 1 through 10 from our decimal system (base 10) to the binary system (base 2). Explain how to make the conversion to another person.

LEARNING OUTCOMES

Project skill: Identifying robot capabilities

Life skill: Processing information

Educational standard: NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved

Success indicator: Identifies questions a robot can and cannot answer

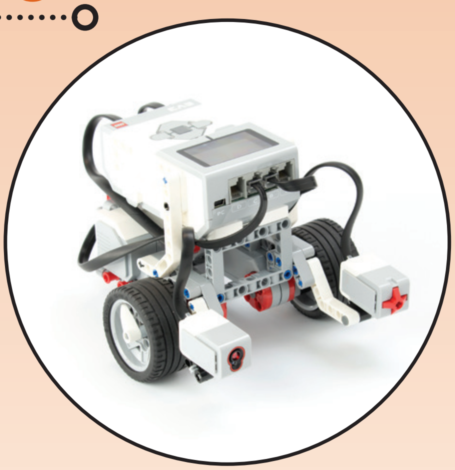
Did you know?

If a sensor on your robot is not accurate enough to stay within your acceptable tolerances, you may need to redesign or reprogram your robot.

Two Sensors Are Better Than One

Now we have used the color sensor to read colors and make decisions. The next step is to add "multitasking" to our program. Multitasking lets the robot to do more than one thing at a time. You have unlimited multitasking possibilities when designing programs for your robot. One common use of multitasking is a "watching" sensor that acts as an emergency stop. If the sensor is tripped, the robot immediately stops moving and ends all programs. An emergency stop is a great idea for robots that are used around people.

WHAT TO DO



Reconnect your touch sensor to the front of your robot and complete the program instructions to add multitasking to your current program. To do so, go to **ohio4h.org/robotics** and watch the video called Activity 11: Two Sensors Are Better Than One. Make sure you have both sensors connected to the right ports.

When you are finished, answer these questions.

Was there anything difficult about completing this video? Explain.

____

____

Why is having the touch sensor on a separate line of code important?

____

____

Why would it be useful to have an emergency stop on a robot?

____

____

How could you use a color sensor as an emergency stop?

____

____

LEARNING OUTCOMES

Project skill: Programming the robot to multitask

Life skill: Mastering technology

Educational standard: NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved

Success indicator: Programs robot to complete a multitasking program

BACKGROUND

We hear a lot these days about the digital world, but what is it? Maybe a better question is, what isn't digital? To answer, you first have to understand computers in general. Computers, when broken down, are really very simple. Reduced to their most basic part, all computers are no more complicated than a light switch that is either "on" or "off." Just like a light switch, computers operate by the flow of electricity where only two options exist: either the switch is on and the electricity is flowing, or it's off and the electricity is stopped.

As computers were developed, scientists decided that writing the words "on" and "off" for each possible instruction was too complex. This led to the invention of binary language. Binary is a numbering system that has only two choices, 1 to represent "on" or 0 to represent "off." By using and combining these two digits in series, the computer can solve math problems, make yes/no decisions, and compare information.

In the program you just created, you used the switch block to enable the robot to make yes/no decisions about colors. When the robot gets a color reading, it compares it with the values in the switch. The robot gets a color reading then compares it with the values in the switch. If the value is red, or "yes," the robot executes that line of code. If the value is not red, or "no," then the robot skips to the next block.

BASE TEN =
10

Did you know?

In our base ten system of counting, the number ten is represented by 10, meaning no 1s and one 10. In a binary, or base two, system, the number ten is written 1010, meaning no 1s, one 2, no 4s, and one 8.

BINARY =
1010

Talking It Over

SHARE Use your own words to describe how the mechanics or hardware of the LEGO® EV3 touch sensor works.

____

____

____

REFLECT Now you have sensor hardware in place and the software to run it. What happens if either component is not working properly?

____

____

____

GENERALIZE Because robots do not have opinions or feelings, what kinds of things are hard for them to decide?

____

____

____

APPLY Describe another program you could write that uses the color sensor.

____

____

____

12 Small Tasks, Big Accomplishments

ACTIVITY 12

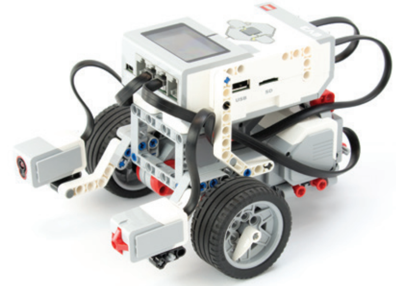
According to The Princeton Review, **robotics engineers** “design robots, maintain them, develop new applications for them, and conduct research to expand their potential.” When taking a 4-H robotics project, you are the robotics engineer. As an engineer, you need to follow an “engineering process.”

WHAT TO DO

Now, let’s see if you can expand your robot’s potential. You know it’s capable of many things, but sometimes it’s hard to decide what, exactly, those things are. To build your knowledge of robotics and to prepare yourself for competition, see if you can program your robot to do the following tasks. Use the table to track your progress.

Ultrasonic and Gyro Sensors attached

Color and Touch Sensors attached



TASK	My robot can do this.	
	YES	NO
Stay within an area defined by tape, fencing, or some other boundary		
“Park” in a garage, then exit, turn around, and park again		
“See” and “kick” a table tennis ball		
Move from point A to point B while avoiding different kinds of obstacles		
Pick up, move, and drop a small object		
Push and pull a wagon or other object with wheels		
Open and close a gate		
Locate and pass through a doorway		
Any other defined task you can think of. Describe it here:		
Any other defined task you can think of. Describe it here:		

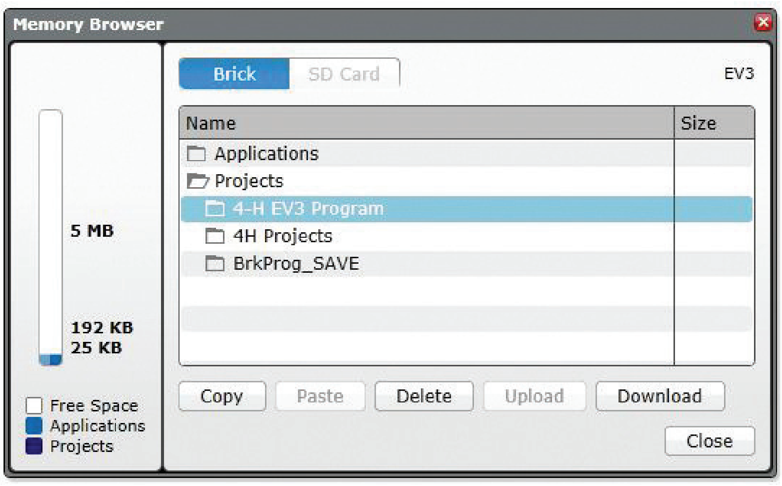
MORE CHALLENGES

People often combine simple tasks to accomplish more complicated ones. Program your robot to complete a series of chores around a house, a farm, or a work site that you create. Then, give a demonstration to your project helper.

TECH TIP

Deleting All Programs from Brick

1. *Make sure the brick is connected to your computer.*
2. *Open the desired project on your EV3 software.*
3. *In the Tools menu, select "Memory Browser."*
4. *From here, you can access the files on your brick and decide what to do with them.*
5. *To delete a file, select it, and then click delete.*



Did you know?

Some robots have been programmed to imitate human behavior, from making decisions to mimicking facial expressions. Robots with this ability are said to feature **artificial intelligence**.

LEARNING OUTCOMES

Project skill: Designing programs to achieve specific goals

Life skill: Mastering technology

Educational standard: NGSS 3-5. ETS1-2: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem

Success indicator: Designs programs that allow the robot to complete assigned tasks

Talking It Over

SHARE Which of the tasks in Activity 12 were difficult to program? Which were easy?

____

____

____

REFLECT As you become more experienced at programming, what new possibilities do you see for your robot?

____

____

____

GENERALIZE Do you consider programming your robot to be a creative process? Why or why not?

____

____

____

APPLY Give your own example of a complicated task that is easy to accomplish when broken down into simple tasks.

____

____

____

GLOSSARY

application software. Programs added to the operating system software to allow users to complete tasks. Examples are browsing the internet, writing a text document, or drawing a picture.

artificial intelligence. A branch of computer science concerned with making computers behave like humans.

automaton. A self-directed machine, usually one that looks and moves like a living thing.

axle. A small rod that is used with a wheel or a gear to turn the wheel or the gear. An axle looks like a plus sign (+) from the end. Most axles are black or gray in color. Axles are also measured in stud length. To determine the length of an axle, use a plate or a brick to measure it.

ball caster. The ball caster is ball mounted inside a plastic socket. When built, it acts as a wheel that can roll in any direction.

brick. The basic building element of the LEGO® system. Bricks are measured by the number of studs they have in width and length. Also a shortened name for the intelligent brick.

driving base. The part of the robot to which other components are attached.

duration. The length of time that something exists or lasts.

encoder. A device that measures and communicates a robot's experience.

firmware. Read-only computer code that translates between the hardware and the software.

frames. A rectangular LEGO® part adds stability to your builds.

friction. The scientific term for two objects rubbing together.

gear. Used to transfer movement from one part of the LEGO® model to another part of the model. Gears come in many sizes and are described by the number of "teeth" they have. In your robotics kit, the smallest gear is an 8-tooth and the largest is a 40-tooth gear.

hardware. The actual pieces and parts of a robot (or computer).

intelligent brick. The microprocessor, or "brain" of your robot.

obstacle detection. The ability to know when something is in the way.

operating system software. A computer's operating system, or OS. Operating software is what makes your computer hardware work.

programming software. Software that helps programmers write more software. It works as a translator to communicate what you want to the computer and its hardware. Programming software is written in a special language that the computer understands.

repeatability. The ability of a robot to conduct itself in the same manner every time a program is run.

resolution. The degree to which an encoder can measure.

robot. A machine that (1) is programmable, (2) is automatic, (3) has multiple uses, and (4) is able to sense its surroundings.

robotics. The science or technology of designing, building, and using robots.

robotics engineers. People who design robots, maintain them, develop new applications for them, and conduct research to expand their potential.

rover. A robot designed to move itself across various surfaces.

sensor. Mechanism that allow a robot to sense its surroundings. Sensors can detect light, touch and sound.

sequential. In a specific order.

servo motor. A small mechanism with a motor, gears, and circuits that controls steering and speed.

software. Computer programming that allows a user to control the hardware. Software can be operating system software, application software, or programming software.

TECHNIC beam. The basic building element in the EV3 robotics kit. A TECHNIC beam has no studs and an odd number (1, 3, 5, 7, etc.) of holes in the side. TECHNIC beams come in various lengths and are measured by the number of holes they have.

TECHNIC brick. Looks like a standard LEGO® brick except it has an odd number of holes in the side. All TECHNIC bricks are measured by the number of studs they have.

TECHNIC connector peg. Connector pegs (also called pins) are used to connect TECHNIC beams and other LEGO® parts.

ANSWER KEY

ACTIVITY 1 *(This activity implies there are right or wrong answers, but people often have differing opinions.)*

Gas Pump

- (X) programmable
- (X) automatic
- ( ) multi-use
- (X) senses surroundings

Is it a robot?

( ) yes (X) no

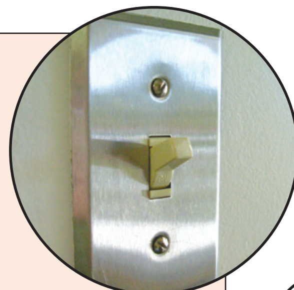
Blender

- ( ) programmable
- ( ) automatic
- (X) multi-use
- ( ) senses surroundings

Is it a robot?

( ) yes (X) no

Light Switch



- ( ) programmable
- ( ) automatic
- ( ) multi-use
- ( ) senses surroundings

Is it a robot?

( ) yes (X) no

Washing Machine

- (X) programmable
- (X) automatic
- ( ) multi-use
- (X) senses surroundings

Is it a robot?

( ) yes (X) no

ACTIVITY 2

1. G
2. H
3. E
4. D
5. C
6. B
7. A
8. F

ACTIVITY 7

1. C
2. A
3. D
4. B

SUMMARY OF LEARNING OUTCOMES

ACTIVITY	PROJECT SKILL	LIFE SKILL	EDUCATIONAL STANDARD*	SUCCESS INDICATOR
PROJECT AREA: THE BASICS				
1. What Is a Robot?	Identifying machines a robot or not a robot	Understanding systems	NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved	Identifies machines as robots or not robots
2. What's What	Identifying and describing the function of LEGO® robotics parts	Understanding systems	NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved	Matches image of part to its name and definition
3. If I Only Had a Brain	Installing and using programming software	Processing information	NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved	Installs and programs intelligent brick software
PROJECT AREA: BUILDING YOUR FIRST ROBOT				
4. Start with Something Simple	Building a robot	Processing information	NGSS MS. ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved	Builds driving base for a basic EV3 robot
5. Let's Get a Move On	Writing a program that enables your robot to move forward	Planning and organizing	NGSS MS. ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success	Programs robot to follow commands and move forward
6. One Step at a Time	Writing a program that enables your robot to follow a path	Planning and organizing	NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved	Programs robot to follow a specified route to completion
PROJECT AREA: SENSORS				
7. Let's Be Sensible	Identifying hardware functions	Processing information	NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved	Identifies the function of each sensor
8. I've Got a Feeling	Writing a program that enables the robot react to its surroundings	Mastering technology	NGSS MS. ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved	Programs the robot to use its sensor and navigate its surroundings
9. Do You See What I See?	Programming the color sensor	Using scientific methods	NGSS 3-5. ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved	Builds and programs the color sensor
10. All the Pretty Colors	Identifying robot capabilities	Processing information	NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved	Identifies questions a robot can and cannot answer
11. Two Sensors Are Better Than One	Programming the robot to multitask	Mastering technology	NGSS 3-5. ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved	Programs robot to complete a multitasking program
PROJECT AREA: WHAT DO YOU WANT YOUR ROBOT TO DO?				
12. Small Tasks, Big Accomplishments	Designing programs to achieve specific goals	Mastering technology	NGSS 3-5. ETS1-2: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem	Designs programs that allow the robot to complete assigned tasks

The educational standards cited here are from the Next Generation Science Standards, which are available in their entirety at **nextgenscience.org**.

I pledge

My head to clearer thinking,

My heart to greater loyalty,

My hands to larger service, and

My health to better living,

For my club, my community, my

Country, and my world.

ohio4h.org

Additional copies of this book and other Ohio State University Extension, 4-H Youth Development publications are available through local OSU Extension offices and online at **estore.osu-extension.org**. Ohio residents get the best price when they order and pick up their purchases through local Extension offices.