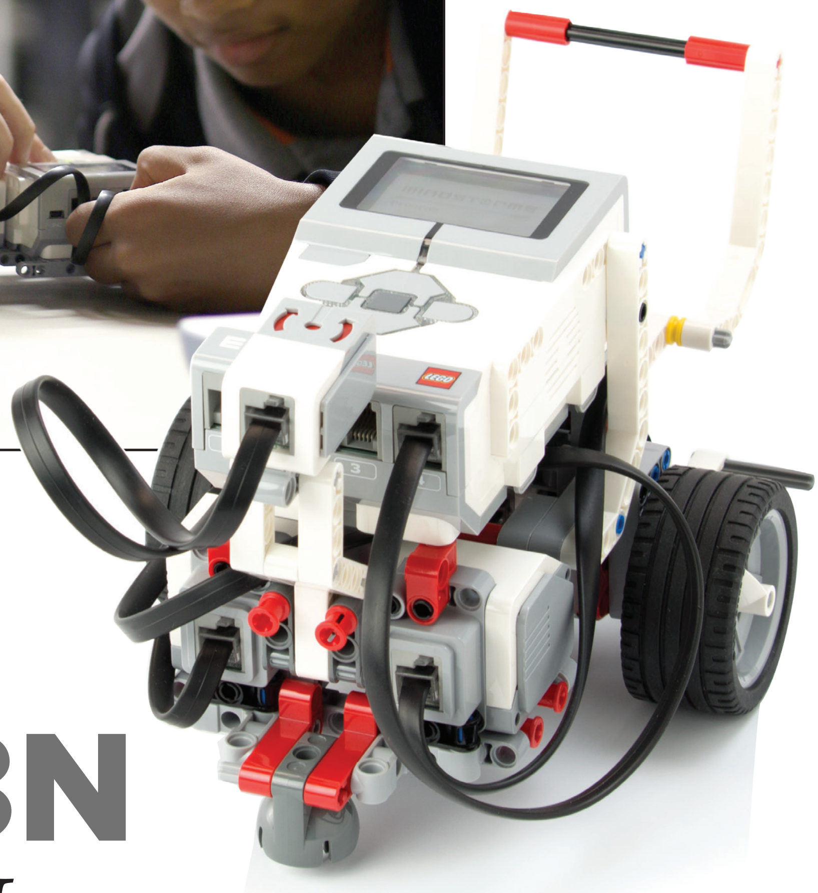
4-H 508

ROBOTICS 2



EV3N *More*

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

Author

Tad Douce, Director of Events, The National Robotics Challenge, Marion, OH

Contributor

Jeff Davidson, Assistant Director of Creative Services, META Solutions, Marion, OH

Reviewers

Bob Horton, Extension Specialist, Educational Design and Science Education, 4-H Youth Development, Ohio State University Extension

Amanda Raines, Program Assistant, 4-H Youth Development, Ohio State University Extension

Production Team

Kerri McTigue, Graphic Designer, The Ohio State University

Maggie Takacs, Program Assistant, 4-H Youth Development, Ohio State University Extension

Jane Wright, Curriculum Manager, 4-H Youth Development, Ohio State University Extension

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

Unless otherwise indicated, photos in this book are from the Ohio State University.

NATIONAL PEER REVIEWED

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

7/17—1.2M—GLOBUS

Contents

Robotics 2: EV3N More requires the use of the same EV3 LEGO® kit used in *Robotics 1 with EV3*. It is intended for youth who are already proficient in building a LEGO® EV3 robot. Kits are available from LEGO® Education, which offers a special bundle that includes the robot, software, rechargeable battery, and storage bin. Youth who take this project also need access to a computer and the internet.

Every activity begins with construction of a special robot configuration. Instructional videos are available to 4-H members via the Ohio 4-H Robotics web page at **ohio4h.org/robotics**.

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. Your interactions should support positive youth development within the framework of the Eight Essential Elements (also known as the Eight Key Elements):

1. A positive relationship with a caring adult
2. An inclusive environment
3. A safe emotional and physical environment
4. Opportunity for mastery
5. Engagement in learning
6. Opportunity to see oneself as an active participant in the future
7. Opportunity for self-determination
8. Opportunity to value and practice service to others

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

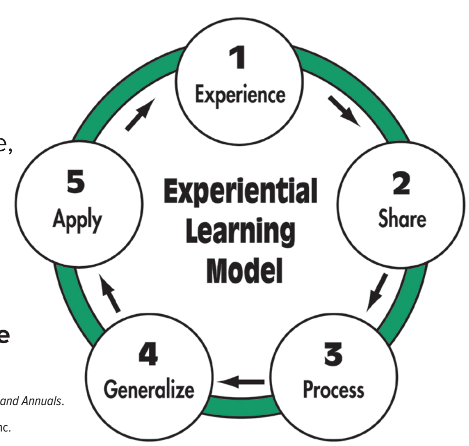
- Guide the youth and provide support in setting goals and completing this project.
- Encourage the youth to apply knowledge from this project book.
- Serve as a resource person.
- Encourage the youth to go beyond the scope of this 4-H project book to learn more about robotics.

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., and J.E. Jones, *Reference Guide to Handbooks and Annuals*.

Member Project Guide

Welcome to *Robotics 2: EV3N More*! This project is designed for 4-H members of all ages who have advanced-level robotics skills and who have completed *Robotics 1 with EV3*. All activities are based on the LEGO® EV3 system.

This project is designed as an individual project, although many 4-H members decide to complete it in small groups.

The LEGO® EV3 robot that was constructed for Robotics 1 is required, and access to a computer and the internet are necessary.

The project can easily be completed in one year. Each activity begins with a short video, but you will need an hour or two to complete each one.

Members who want to continue in robotics are encouraged to design their own self-determined robotics projects with the Robotics Master, available at **ohio4h.org/robotics**.

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

PROJECT GUIDELINES

Step 1: Complete **all seven** activities.

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

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

Step 4: Write a project summary and take part in a project review.

STEP 1:

Project Activities

Complete **all seven** activities. The More Challenges activities are optional. When you begin an activity, jot down the date you start it. When you finish an activity, review your work with your project helper. Then ask your project helper to initial and date your accomplishment.

ACTIVITY	DATE COMPLETED	PROJECT HELPER INITIALS
1. Get a Grip		
2. Data Driven Decisions		
3. What Kind of World Do We Live in?		
4. We've Got Trouble		
5. And More Trouble		
6. Math-a-Mania		
7. That Seems Logical		

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 show the interesting things you are learning about? Here are some ideas:

- Attend a clinic, workshop, demonstration, or speech related to engineering or robotics.
- Prepare an announcement for school, radio, television, or the internet on an event related to engineering or robotics.
- Help organize a club meeting based on this project.
- Go on a related field trip or tour.
- Host a workshop to share tips and tricks about working on robots and other science, technology, engineering and math subjects.
- Prepare your own demonstration, illustrated talk, or project exhibit.
- Participate in county judging.

Once you have a few ideas, record them here. Complete **at least two** learning experiences. Then, describe what you did in more detail. You may add to or change these activities at any time. 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 tools and supplies needed to assemble a robot.*	*5/5/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 as 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 robotics.
- Organize a science, engineering, or technology event in your area.
- Encourage someone to take a science, engineering, or technology project.
- 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
Organized a club field trip to the robotics lab at the local middle school.	*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 this space 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...

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 judgings.

1 Get a Grip

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

In *Robotics 1 with EV3* you built a robot that could drive around, detect an object with a touch sensor, look for colors, detect and follow a black line, and sense how far it was from an object using an ultra-sonic sensor. Whew! That was a lot of learning! Believe it or not, you have just scratched the surface of all the things your little robot can do.

The robot you built in *Robotics 1 with EV3* is referred to as the **driving base**. It is called a **mobile robot** or **rover**, because it can move from place to place under its own power. Mobile robots can have wheels, like your robot, or tank treads or perhaps even legs. Regardless of how they get around, mobile robots are very exciting and fun to work with.

Now, we want to make your robot rover a bit more useful. Your robot can drive around and get from place to place but . . . then what? The poor robot has no arms. You need to add a third motor with a collection tool so your robot can interact with its environment in a meaningful way.

WHAT TO DO

Caution! Be sure the collector arm is straight up before running the program!

If your **collector** arm is not already built, refer to the kit's instructions to build it. They were included with your kit and are also available at **ohio4h.org/robotics**. To program your robot, go to the same web page and watch the video called Activity 1: Get a Grip.

All set? Try to have your robot retrieve different kinds of objects. Good examples include a spoon, golf ball, ping-pong ball, small book, a pen, or pencil.

Can you modify your collector to deal with different objects?

Record your success in the table below and make notes about any special considerations.

OBJECT	SUCCESS? (Yes or No)	NOTES

Talking It Over

SHARE Why do you think mobile robots seem more exciting than robots that cannot move from place to place?

____

____

REFLECT When you tried to have your robot collect different objects, which ones worked and which ones did not? Can you make a general rule about what it can or cannot collect?

____

____

GENERALIZE What challenges would you face if you tried to design a collection device that could pick up whatever it is given?

____

____

____

APPLY What other types of attachments could you create to make your rover more useful?

____

____

MORE CHALLENGES

Create a program for your robot and collector that collects several objects and brings them back to a single location

LEARNING OUTCOMES

Project skill: Building and programming a robot to pick up and move objects

Life skill: Mastering technology

Educational standard: 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 a LEGO® EV3 robot to pick up and move objects

BACKGROUND

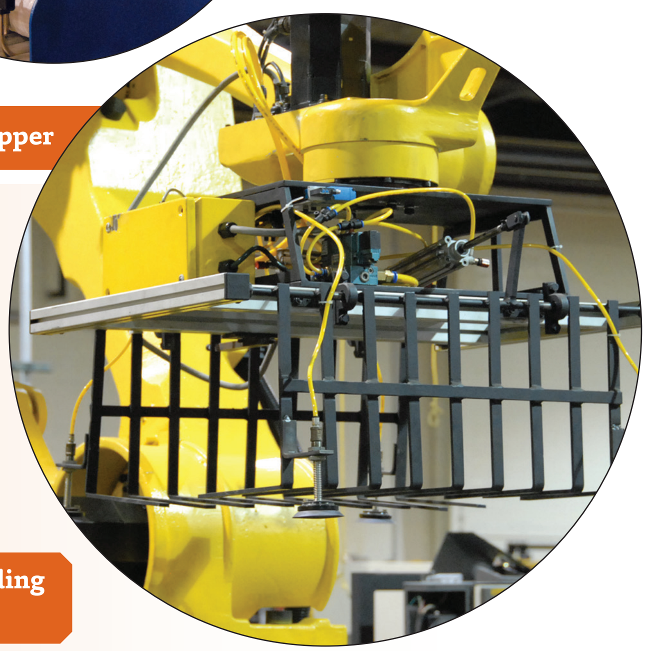
The collector is a type of **end effector**. End effectors are the items at the end of a robotic arm. Typically this device is what really makes the robot useful or effective. There are many different types of end effectors for robots. Some, such as grippers, electro magnets and suction cups, are used to attach to or grip objects and move them from one place to another. Other specialized end effectors, such as welders, paint sprayers, grinders and drills, enable robots to modify a part as a step in the assembly line process. These end effectors are called **process tooling** because they are part of the manufacturing process. You can see videos of many different kinds of industrial robotic arms and end effectors at **robots.com**.

Did you know?

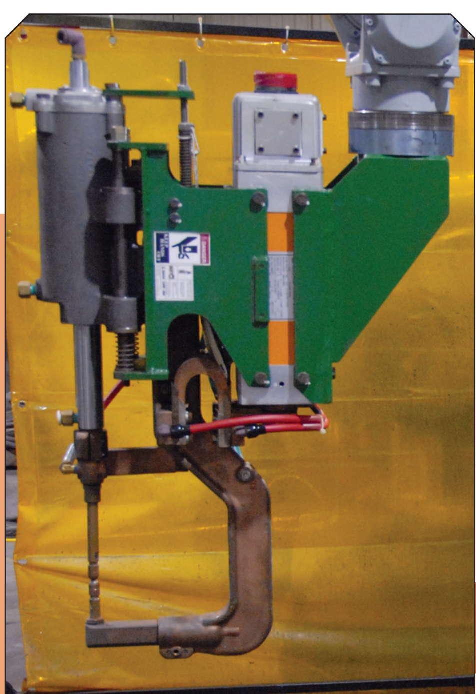
Shadow Robot Company in the United Kingdom has developed one of the worlds most advanced robot hands. The Shadow Dexterous Hand-C6 has 24 movements that imitate the human hand movement and sensitivity as closely as possible. See more at **shadowrobot.com**.

Arch Welding Tool

Bag Gripper with Suction



Bag Gripper



Spot Welding Gun

ROBOTS IN INDUSTRY

The use of robots in industry is becoming common, with specialized robots performing all sorts of functions faster and more reliably than humans. RobotWorx, a company in Marion, OH, that supplied these images, is dedicated to helping other companies integrate robots into their production processes. It even buys and sells robots and robot parts. To learn more, go to **used-robots.com**.

Drill

Polishing Robot

Plasma Cutting Torch

Fanuc M1iA Spider Robot

Claw Gripper

Suction Gripper

2 Data Driven Decisions

In Activity 1 you used the **action palette** from the EV3 programming software. This activity requires you to deal with information instead of just motors. The **data operations palette** gives you a whole new set of tools that you can use to make your programs more powerful and useful. The data operations palette gives you the ability to use **data wires**. Data wires let you add new connections between your programming blocks so the robot can better adapt to its environment.

WHAT TO DO

To build and program your robot, go to **ohio4h.org/robotics** and watch the video called Activity 2: Data Driven Decisions.

Find an object like a book or a folder and run the program using four different distances from the ultrasonic sensor. Use a ruler to measure how far your robot travels each time you run the program. Record your information on the chart below.

RUN	Distance from Sensor	Distance Travelled
1		
2		
3		
4		

Now see if you can use this program to make your robot run for exactly 20 centimeters.

Could you do it? (Circle one) YES NO

If you did get it to work, how far away was your folder from the ultrasonic sensor when you ran the program? ____________________

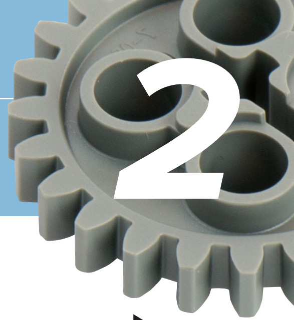
LEARNING OUTCOMES

Project skill: Creating a program to make sensor values control motor speed

Life skill: Mastering technology

Educational standard: 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 a LEGO® EV3 so that its speed is based on input from the ultrasonic sensor



Talking It Over

SHARE How many attempts did it take to reach the 20 centimeter distance?

REFLECT Why did we compare the ultrasonic sensor reading to be sure it wasn't greater than 100?

GENERALIZE Can you think of a real device or robot that changes how it operates based on the input from its sensors?

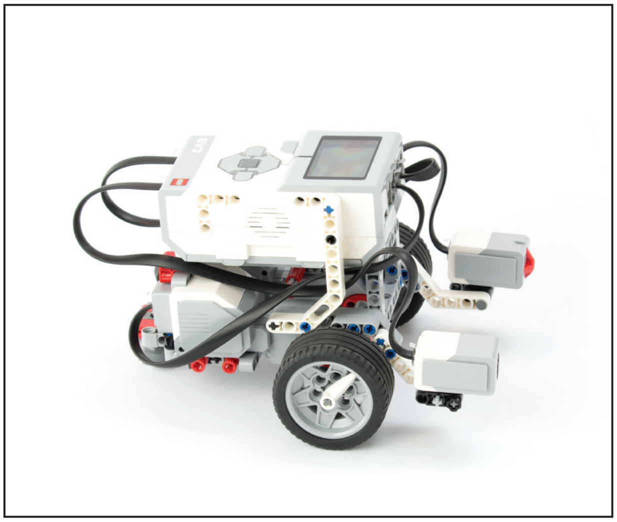
APPLY What other sensors could you use to control the speed of your robot?

MORE CHALLENGES

Can you design a robot that speeds up and slows down to follow an object as you move it away from the ultrasonic sensor?

BACKGROUND

Control systems are how devices such as sensors change the output of a mechanical system in **real time**. For example, think about a car's cruise control. When a driver sets the cruise control to the desired speed the car has sensors so the cruise control can accelerate the car when going up a hill or let off of the accelerator when going down a hill. This way the car stays as close as possible to the speed the driver desires. What happens if the driver pushes the brake? That's right—the cruise control senses that the driver needs to change the speed and shuts off immediately. This type of control system is called a **closed-loop** system. It is "closed" because it is constantly monitored by sensors that allow the system to make adjustments to the output.



Adding more sensors to the control loop of a system makes it more accurate and more responsive. Think about cruise control again. What happens if a driver doesn't see a car in front of him slowing down? If the driver doesn't hit the brake the cruise control just keeps going the speed that was set. This most likely would cause a serious accident. Some new cars have ultrasonic sensors added to their fronts. This sensor is used to turn off the cruise control if an object is too close to the front of the vehicle. This helps avoid the collision by alerting the driver to the problem.

Did you know?

"Real time" is a synonym for the present. It means "as events happen" or the actual time during which a process or event occurs. In computing, real time processing means input data is processed within milliseconds so that it is available almost instantly as feedback.

What Kind of World Do We Live In?

3

In Activity 2 you learned about data wires and used data to modify your robot's actions in real time based on the sensor reading. The particular data you used was a number. The number came from the EV3 Intelligent Brick using the ultrasonic sensor to measure the distance in centimeters. That number was then "fed" into your move block to control the speed of your robot.

Sometimes it is helpful to see the data that your robot is sensing. You can modify the Activity 2 program to display the data from the ultrasonic sensor as a number on the screen. You also will learn about other types of data that your robot can process.

WHAT TO DO

To learn more about **data types** and display, go to **ohio4h.org/robotics** and watch the video called Activity 3: What Kind of World Do We Live In.

Talking It Over

SHARE Why did we want to have a one second wait between the display block and the steering block?

____

____

REFLECT What is the most important thing about programming robots you learned in Activities 1-3?

____

____

GENERALIZE Name four devices in your house that display numbers on a screen like you have on your EV3 robot.

____

____

APPLY How could you get the robot to display the sensor reading in inches, instead of centimeters?

____

____

BACKGROUND

Data wires carry information from one block to another, and each data wire has a type. The type refers to the kind of information that is being carried. See the table for more information on the different types.

Type	Block Input	Block Output	Block Output Data Wire
Logic			
Numeric			
Text			

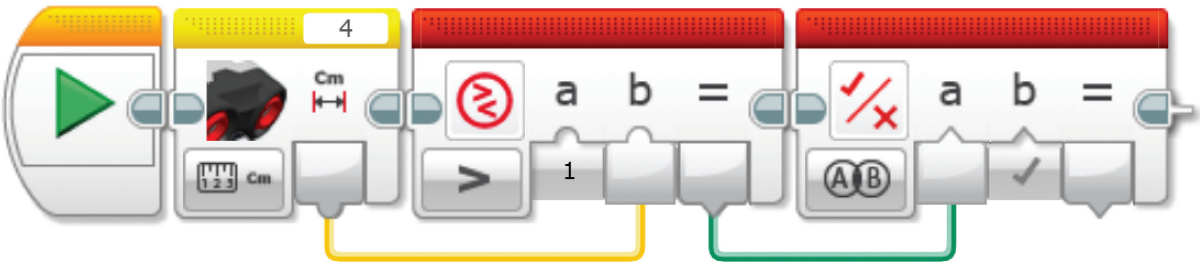
- **Logic type** data wires represent a true or false value and are green. The only two possible logic values are true and false.
- **Numeric type** data wires represent a number. A numeric value can be positive or negative, and it can have digits after the decimal point. Numeric data wires are yellow. Some examples are 3, 1.25, -75, 87456.3487, -0.002.
- **Text type** data wires, which are orange, represent a text string—a sequence of text characters, similar to a text message. A text value can be a word, a single letter, a sentence, or any sequence of characters. Some examples are "Hello," "A," "This is a longer text," or Aa123@#$%-+=.

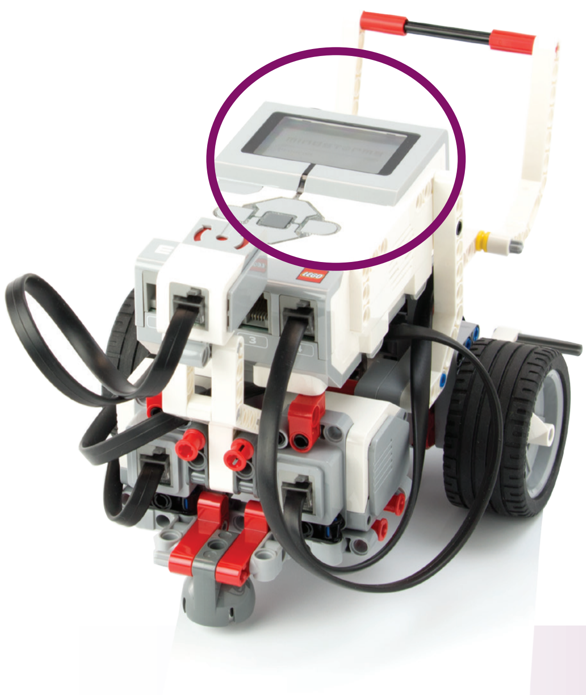
Using data wires is a great way to create more complex programs for your robot. By using sensor data wires in combination with logic and data operations you can quickly create new ways for your robot to interact with its environment.

MORE CHALLENGES

Can you make a program that displays the distance on the screen in both inches and centimeters?

Data wires carry specific types of data. Each data wire carries a specific type of data between blocks. For example, if a data wire is dragged from a logic plug on a block's data hub, it can be connected only to a logic plug on another block's data hub.





Did you know?

The screen on your robot is called an LCD screen. LCD stands for liquid crystal display.

LEARNING OUTCOMES

Project skill: Programming a robot to display sensor data

Life skill: Understanding systems

Educational standard: 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 a LEGO® EV3 robot to display sensor data

We've Got Trouble

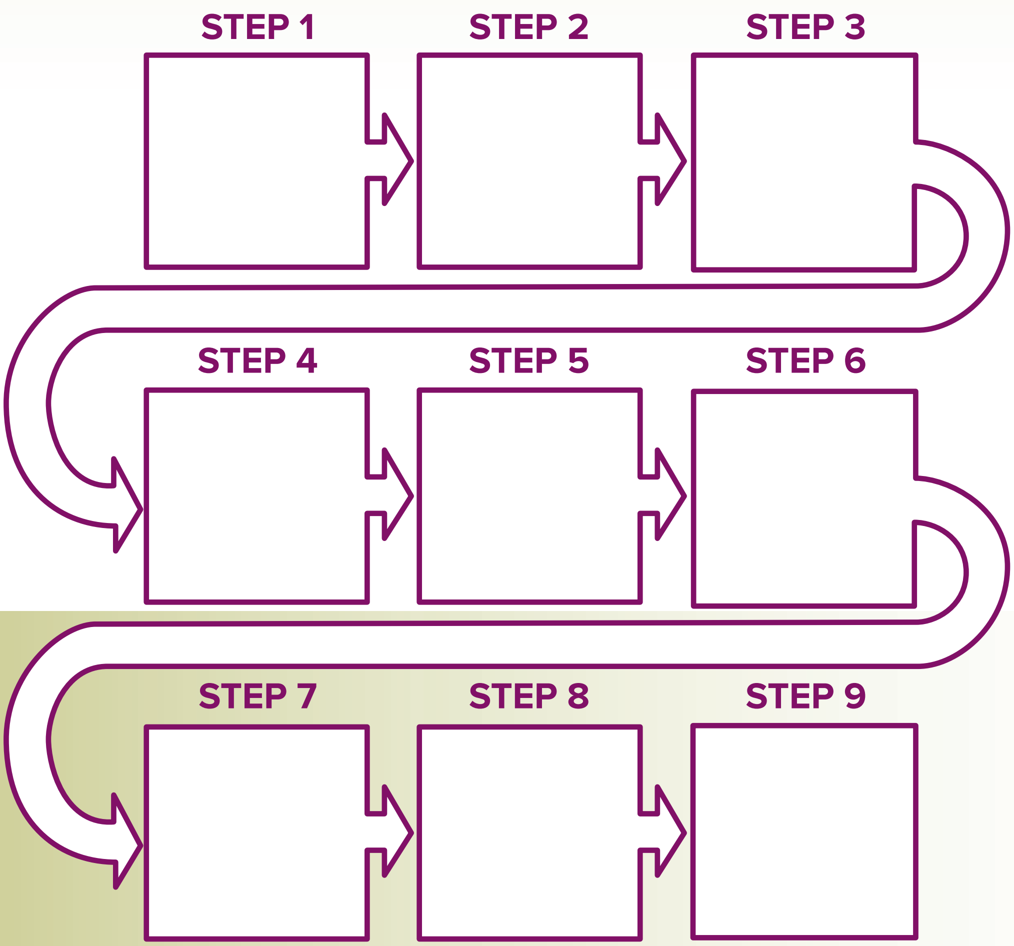
Even programming experts create programs that do not work quite as expected. As you learn about robotics, you will too. Figuring out what is wrong with your program can be very frustrating to say the least!

However, now that you have been introduced to displaying data on the screen of the EV3, **troubleshooting** your programs can be much easier. One effective troubleshooting approach is to use the data wires in combination with the EV3 screen to monitor what is happening with your sensors. Creating a program that displays a symbol is a good way to detect the step in the program that has an error.

WHAT TO DO

To learn how to troubleshoot your robot with sensor data on the screen in real time, go to **ohio4h.org/robotics** and watch the video called Activity 4: We've Got Trouble.

Given what you now know about displaying data values from a robot's sensors in real time, create a general list of steps to use when solving a problem with your robot. It can have as many or as few steps as you think are necessary, Use the space below or attach your own page to this one.



Talking It Over

SHARE Why is troubleshooting an important skill to develop as a robotics engineer?

REFLECT The video asked, "Is it a sensor problem or a program problem?" When you are troubleshooting a problem with your robot you need to eliminate errors one at a time. Why do you think this is important?

GENERALIZE Give an example of a problem you had to work through that did not have an obvious answer. How did you solve it?

APPLY Can your robotics troubleshooting steps be adapted to solving other problems? Explain.

LEARNING OUTCOMES

Project skill: Identifying and correcting problems in robot performance by displaying data values in real time

Life skill: Solving problems

Educational standard: 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 and corrects problems in the performance of a LEGO® EV3 robot by displaying data values in real time

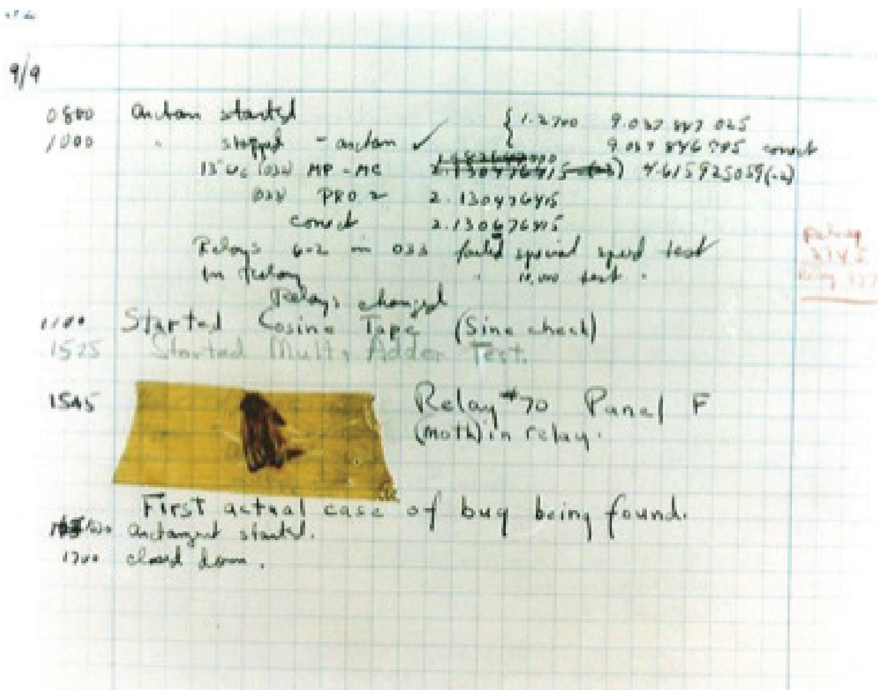
MORE CHALLENGES

Changing the state setting on the wait for touch sensor blocks was one way to fix the error in the program. Can you figure out another way to fix the issue?

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? Troubleshooting a computer program is often referred to as **debugging**. You might hear someone say, "I think you have a bug in your program." This does not mean there is a real insect in your robot. It just means that something is not working quite as well as expected. But where did that term come from?

Well, the story goes something like this. In 1947 the operators of the Mark II, an early computer at Harvard, found a moth trapped in an electrical relay. This moth was causing a short in the electrical system therefore making the computer malfunction. This bug was carefully removed and taped to the Harvard Computation Laboratory log book.



So, from the first "bug", we still call errors or glitches in a program a bug.

Did you know?

Sakichi Toyoda, founder of Toyota Motor Corporation, developed the "5 Whys" method of troubleshooting. Basically, when there is a problem the troubleshooter asks "Why?" and then tries to determine the answer. By asking "Why?" five times, Toyoda found that you usually get to a root cause of the problem.

And More Trouble

Troubleshooting is a very important part of programming and designing a robot. The concept of **variables** is another concept that you will need to understand. Variables are a way to mathematically store data so you can use it later in your program. Variables are very useful in programming robotics. By using them in your programs you can collect information or data from the sensors of your robot and store this information to be analyzed later.

WHAT TO DO

To learn about variables and how you can use them in your EV3 programming go to **ohio4h.org/robotics** and watch the video called Activity 5: And More Trouble.

Run your program ten times and record the three light sensor readings on the chart here. As much as possible, start your robot in exactly the same position. Calculate the average of each reading at the bottom of the chart by following these two easy steps:

1. Add each column. This is the sum of the readings.
2. Divide the sum by 10 to calculate the average. This type of an average is called a mean.

Run	Reading 1	Reading 2	Reading 3
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Sum			
Average (Mean)			

LEARNING OUTCOMES

Project skill: Programming a robot to create, store, and retrieve a data variable

Life skill: Solving problems

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

Success indicator: Programs a LEGO® EV3 robot to create, store, and retrieve a data variable

Talking It Over

SHARE When you ran your program did you find that the readings varied greatly from run to run or were they pretty much the same each time?

REFLECT You were asked to find the average (mean) of the sensor readings for ten "runs." What do you think would happen to your averages if you ran your robot five times instead of ten?

GENERALIZE Give four examples of where you have heard of averages used with data in the real world?

APPLY Besides the example in the video (taking radiation readings), where do you think a robot might be more useful than a human for collecting data about the environment of a location?

MORE CHALLENGES

Design a program that collects light sensor readings from four different places in the cave.

BACKGROUND

Math is a subject students sometimes try to avoid in school, but it's really useful. If you are interested in robotics, computers, electronics or any kind of engineering, knowledge of mathematics is essential.

One thing related to any job in engineering is performing tests. No, not tests like the ones you have in school. These tests are about figuring out if a particular design or solution will work. When engineers test a design, they keep track of results on a chart like the one in this activity. Once the results are gathered, engineers use math to decide if the design is working the way that was intended.

Below are a few math terms you will definitely use as you work in robotic design, research and testing. If you don't know them already, learn them now.

AVERAGE	A single number that represents the center of a set of values. An average can be expressed as the mean, mode or median.
MEAN	This is the most commonly used type of average. To find the mean of a set of numbers, add the numbers in the set and divide by how many numbers are in the set.
MODE	The number that occurs the most often in a list. For example, in the set {2, 3, 3, 3, 4, 5, 5}, 3 is the mode.
MEDIAN	The value for which half the numbers in the set are larger and half are smaller. If there are two middle numbers, the median is the mean of the two middle numbers. For example, in the set {1, 2, 5, 7, 9, 12, 13, 15, 18}, the median is 9, the number in the middle of the set. In the set {1, 2, 5, 7, 8, 12, 13, 15, 18, 19}, the median is 10 because both 8 and 12 are in the middle. The mean of 8 and 12 is 10 (8 + 12 = 20; 20 ÷ 2 = 10).
SUM	The result of adding a set of numbers. For example, 1 + 3 + 5 + 6 + 3 + 2 = 20.
DIFFERENCE	The result of subtracting two numbers. For example, the difference between 8 and 15 is 7 (15 - 8 = 7).

Did you know?

Statistics is the science of the collecting, organizing, and understanding data. It includes the planning of data collection such as creating surveys and experiments.

Math-a-Mania

Now you have the ability to use the data from the sensors and store this information as a variable. The next step is not only being able to display the data, but to have the robot modify this data and use it to change the output action of the robot. This is called a **computation**.

WHAT TO DO

To learn more about the mathematical functions your robot can do, and how to use them in your EV3 programming, go to **ohio4h.org/robotics** and watch the video called Activity 6: Math-a-Mania.

Change the operation of the math block in your program to "addition" and run the program.

How did this change the actions of the robot?

____

____

Repeat this with the "subtraction" function and the "multiplication" function and record your observations below.

Subtraction results? ______________________________

____

Multiplication results? ______________________________

____

A robot can be programmed to make decisions based on numbers but it cannot make decisions based on opinion the way humans do. Of the following questions, which could be made by a robot, a human or both?

	Robot	Human	Both
Which color is darker?			
Where is the warmest place in the room?			
How does sunshine feel?			
Is a painting beautiful?			

Answer key is on page 32.

Talking It Over

SHARE Explain how the "multiplication" and "division" functions affected the sound from the robot differently.

____

____

____

REFLECT Why do you think the addition and subtraction functions had little effect?

____

____

GENERALIZE Can you think of a real life use where you would want a robot to calculate the value of a sensor? Explain.

____

____

____

APPLY Explain how the robot could calculate how far it traveled using the input from the motor rotation sensor and the math block.

____

____

____

MORE CHALLENGES

Design a single program that changes speed by dividing or multiplying the reading from a light sensor.

LEARNING OUTCOMES

Project skill: Programming a robot to do a computation using values from sensors

Life skill: Understanding systems

Educational standard: 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 a LEGO® EV3 robot to do a computation using values from the light sensor

BACKGROUND

We hear a lot these days about digital. What is digital? Or maybe a better question is what isn't digital? When considering what is or isn't digital you first need an understanding of computers in general.

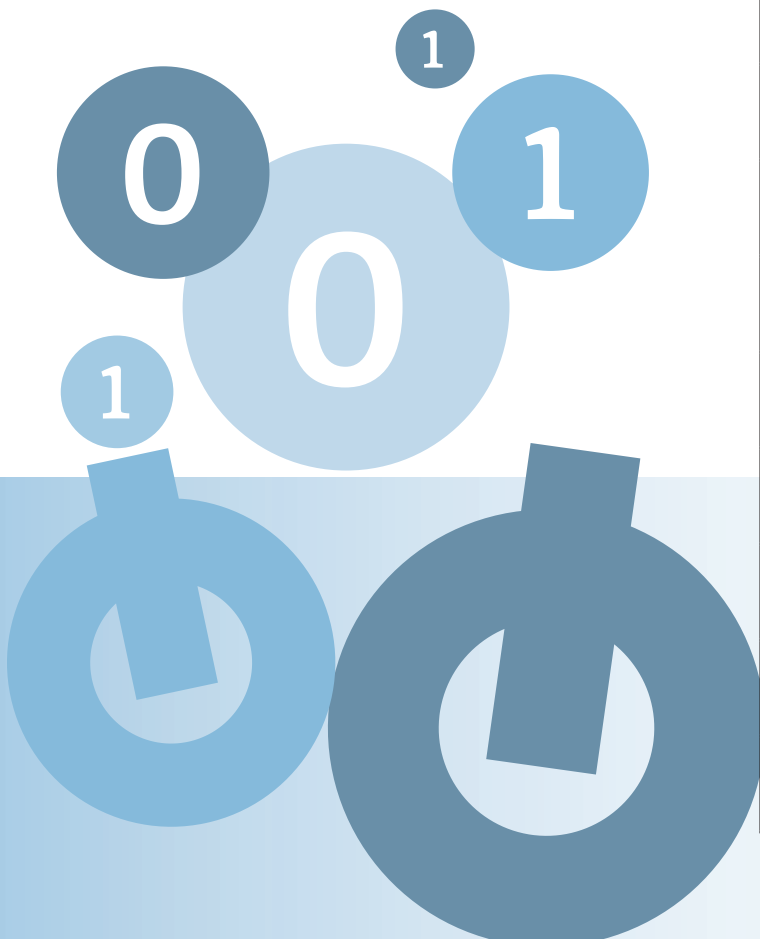
When broken down to their simplest parts, computers are really very simple. They are no more complicated than a simple light switch. It's either on or off, true or false. This is because computers operate by the flow of electricity and you have only two choices. Either the switch is on and the electricity is flowing, or it's off and the electricity is stopped.

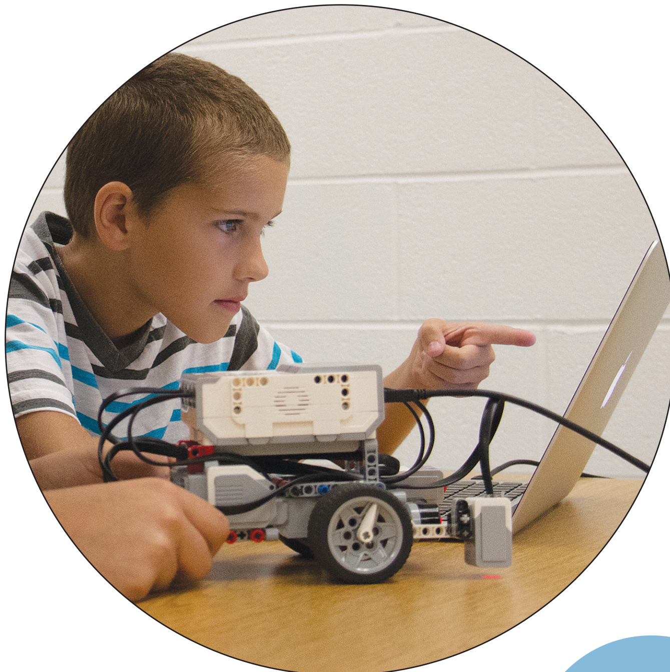
As computers were developed, it was decided writing true or false for all the instructions was too complex. Instead, **binary code** was invented. A binary numbering system has two choices, 1 to represent "true" or 0 to represent "false." By using and combining these two digits in different combinations and in series, a computer can solve math problems, make yes/no decisions and compare data.

Complete the decimal to binary conversion chart at right:

Decimal	Binary
0	0000
1	0001
2	0010
3	
4	0100
5	
6	
7	0111
8	
9	
10	

Answer key is on page 32.





Did you know?

Most power switches now use a symbol that looks like this: ⏻

This is actually a “1” and a “0” that represents the binary on and off.

To learn more about how computers work go to **educate.intel.com/en/TheJourneyInside/ExploreTheCurriculum.**

1 0 0 0 1 0 0 1 1

7 That Seems Logical

You have reached the last programming activity of this project! The first six activities covered many concepts, but this is perhaps the most important. **Logic**! Simply put, logic, when it refers to programming, is a system or set of principles guiding the way elements work in a computer as it performs a specific task.

Understanding logic helps you predict and troubleshoot what happens in your program. As you move forward, knowing how to apply logic is essential to improving your programming skills. Your programs give your robot the ability to process input from its sensors. Your programming logic gives your robot the ability to act. Predicting results before you run a program is a skill that requires many hours of study and practice. Even then, you most likely will find your little robot does not always function as expected.

WHAT TO DO

For a very simple illustration of applying logic to programming, complete the table below by deciding whether each statement is true (use "1") or false (use "0"). Then go to **ohio4h.org/robotics** and watch the video called Activity 7: That Seems Logical.

				
The figure is standing.				
The figure has a hat.				
The figure is standing AND the figure has a hat.				
The figure is standing OR the figure has a hat.				

Answer key is on page 32.

LEARNING OUTCOMES

Project skill: Programming a robot to make complex decision

Life skill: Reasoning

Educational standard: 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 a LEGO® EV3 robot to make a complex decision

Talking It Over

SHARE Why is it important to understand logic when programming your robot?

REFLECT You used the OR and AND logic functions of your program. Using the truth tables in the background information on the following page, predict the behavior of your robot if you used the XOR and NOT logic functions.

GENERALIZE Mastering logic means being able to write your program in simple understandable steps. Make a list of the steps your robot program goes through in the program you wrote.

APPLY Using the same format from the question above, write out the steps to explain how to make a peanut butter and jelly sandwich.

MORE CHALLENGES

Design a single program that stops your robot if it detects a white line or sees an object within eight inches of the robot.

Did you know?

The fastest computer in the United States, called Titan, is housed at the Oak Ridge National Laboratory in Tennessee. This supercomputer was built by Cray Incorporated and can solve 17,590,000,000,000,000 equations in a second! That's 17.59 quadrillion operations every second. Titan has 710 terabytes of memory and uses as much power as 9,000 homes!

BACKGROUND

In this activity you used the logic block to stop your robot if the color sensor saw darkness or if the ultrasonic sensor detected something less than 5 centimeters away. The logic block can perform four operations: And, Or, Not and XOr. These operations are called Boolean operations and are part of a system called **Boolean logic**. Boolean logic was named after George Boole, who first defined a mathematical system of logic in the mid-19th century.

Boolean logic has many uses in electronics, computer hardware, and software. It is the basis of all modern digital electronics including computers. Each of these operations causes very different results in a program. To figure out how a Boolean operator affects your program you can use a tool called a **truth table**. A truth table is a way to express all of the possible outputs of a Boolean operator.

Let's look at some examples of how this works. In this activity you used an "OR" operator so your robot would stop if the color sensor saw darkness "OR" if the ultrasonic sensor detected something less than 5 centimeters away. If you refer to the "OR" truth table below you can predict the behavior of the robot. Look under the "Input" side of the table. You know from the background information in Activity 6 that the "0" represents "off" or "false" and the "1" represents "on" or "true." So, if both sensors are not sensing anything, both would be off and the operator would output an "off" or "false" result.

However, if either sensor is triggered the truth table indicates that the output result is "on" or "true." You will also notice that if both the "A" and "B" inputs are true the output is also true.

Now look at the "And" truth table. You will notice that the only situation that creates a "true" or "on" output is if both the "A" AND "B" inputs are "true."

You can use these truth tables for your advanced programming to make sure your robot works the way you designed it.

OR		
INPUT		OUTPUT
A	B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

XOR		
INPUT		OUTPUT
A	B	A XOR B
0	0	0
0	1	1
1	0	1
1	1	0

AND		
INPUT		OUTPUT
A	B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

NOT	
INPUT	OUTPUT
A	NOT A
0	1
1	0

action palette. The set of LEGO® EV3 program commands that allows you to make your robot perform certain activities such as turning, making sounds, displaying text and images, etc.

binary code. Computer processing instructions that use the binary numbering system of using 1 for true and 0 for false.

Boolean Logic. A system named after George Boole that uses algebra for logical operations and is the basis for all modern digital electronics.

closed-loop. A kind of control theory in which input from sensors is constant, allowing for constant adjustments.

collector. A tool on a robot used to collect objects. A collector has to be designed and built with the object(s) it is supposed to collect in mind.

computation. A term for information processing in general that is more than the simple calculation of numbers.

control system. A device or set of devices that manages, commands, directs, or regulates the behavior of other devices or systems.

data operations palette. The set of LEGO® EV3 program commands that allows you to make your programs more powerful and useful by manipulating data.

data type. The form of information in a database, either numbers, text, or logic (true or false).

data wires. In LEGO® EV3 programming, data wires serve as connectors that let you add new connections between your programming blocks. There are three types: logic, numeric and text.

debugging. Finding whatever it is in a computer program that is causing the robot to behave in an unexpected way.

driving base. The basic frame for your robot, completed during Robotics 1.

end effector. A device (usually a tool) at the end of a robotic arm.

logic. In programming, a system or set of principals guiding the way elements work in a computer as it performs specific tasks.

logic type. Data represented by a true or false value. In LEGO® EV3, green data wires are used for logic type data.

mobile robot. A robot with the capacity to move around from place to place under its own power; also called a rover.

numeric type. Data represented by a number. In LEGO® EV3, yellow data wires are used for numeric type data.

process tooling. Specialized end effectors—such as welders, paint sprayers, grinders, and drills—that enable robots to modify a part as a step in the assembly line process

real time. The actual time during which a process or event occurs. In computing, real time processing means input data is processed within milliseconds so that it is available almost instantly as feedback.

rover. See mobile robot.

statistics. The science of collecting, organizing, and understanding data.

text type. Data represented by a text string. In LEGO® EV3, orange data wires are used for text type data.

troubleshooting. Identifying and solving problems or difficulties.

truth table. A way to summarize all the possible outputs of a Boolean operator, like AND, OR, XOR, and NOT.

variable. An element that is able to be changed or adapted.

ANSWER KEY

ACTIVITIES 1-5 *Answers to activities 1-5 will vary.*

ACTIVITY 6

Change the operation of the math block in your program to “addition” and run the program.

How did this change the actions of the robot?

The robot adds 2 to the sound sensor reading and uses this as the power level for the move block.

Repeat this with the “subtraction” function and the “multiplication” function and record your observations below.

Subtraction results? *The robot subtracts 2 from the sound sensor reading and uses this as the power level for the move block.*

Multiplication results? *The robot multiplies the sound sensor reading by 2 and uses this as the power level for the move block. The robot moves much faster.*

	Robot	Human	Both
Which color is darker?			*X*
Where is the warmest place in the room?			*X*
How does sunshine feel?		*X*	
Is a painting beautiful?		*X*	

Decimal	Binary
0	0000
1	0001
2	0010
3	*11*
4	0100
5	*101*
6	*110*
7	0111
8	*1000*
9	*1001*
10	*1010+*

ACTIVITY 7

				
The figure is standing.	*1*	*1*	*0*	*0*
The figure has a hat.	*1*	*0*	*1*	*0*
The figure is standing AND the figure has a hat.	*1*	*0*	*0*	*0*
The figure is standing OR the figure has a hat.	*1*	*1*	*1*	*0*

SUMMARY OF LEARNING OUTCOMES

ACTIVITY	PROJECT SKILL	LIFE SKILL	EDUCATIONAL STANDARD*	SUCCESS INDICATOR
1. Get a Grip	Programming a robot to make a complex decision	Mastering Technology	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 a LEGO® EV3 robot to pick up and move objects
2. Data Driven Decisions	Creating a program to make sensor values control motor speed	Mastering Technology	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 a LEGO® EV3 so that its speed is based on input from the ultrasonic sensor
3. What Kind of World Do We Live In?	Programming a robot to display sensor data	Understanding Systems	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 and corrects problems in the performance of a LEGO® EV3 robot by displaying data values in real time
4. We've Got Trouble	Identifying and correcting problems in robot performance by displaying data values in real time	Solving Problems	3-5-ETS1-3. Plan and carry out fair tests in which variable are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.	Programs a LEGO® EV3 robot to create, store, and retrieve a data variable
5. And More Trouble	Programming a robot to create, store, and retrieve a data variable	Solving Problems	3-5-ETS1-3. Plan and carry out fair tests in which variable are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.	Programs a LEGO® EV3 robot to create, store, and retrieve a data variable
6. Math-a-Mania	Programming a robot to do a calculation using values from sensors	Understanding Systems	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 a LEGO® EV3 robot to do a calculation using values from the light sensor
7. That Seems Logical	Programming a robot to make a complex decision	Reasoning	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 a LEGO® EV3 robot to make a complex decision

** The educational standards cited here are from the Next Generation Science Standards. They 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.