Let the Good Ideas Roll!

Grades 6-9

SCALE K-12

SCalable Asymmetric Lifecycle Engagement

PURDUE UNIVERSITY
INSPIRE Research Institute for Pre-College Engineering

INDIANA UNIVERSITY
SCHOOL OF EDUCATION
Bloomington

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Cover Information

Unit Title: Let the Good Ideas Roll!

Grade Level Range: Grades 6-9

Acknowledgments

Teacher Authors

Ricci Barber
Brian Bettag
Justin Resler

Project Authors

Azizi Penn
Rachel Gehr
Tamara Moore
Selcen Guzey
Greg Strimel
Morgan Hynes
Kerrie Douglas

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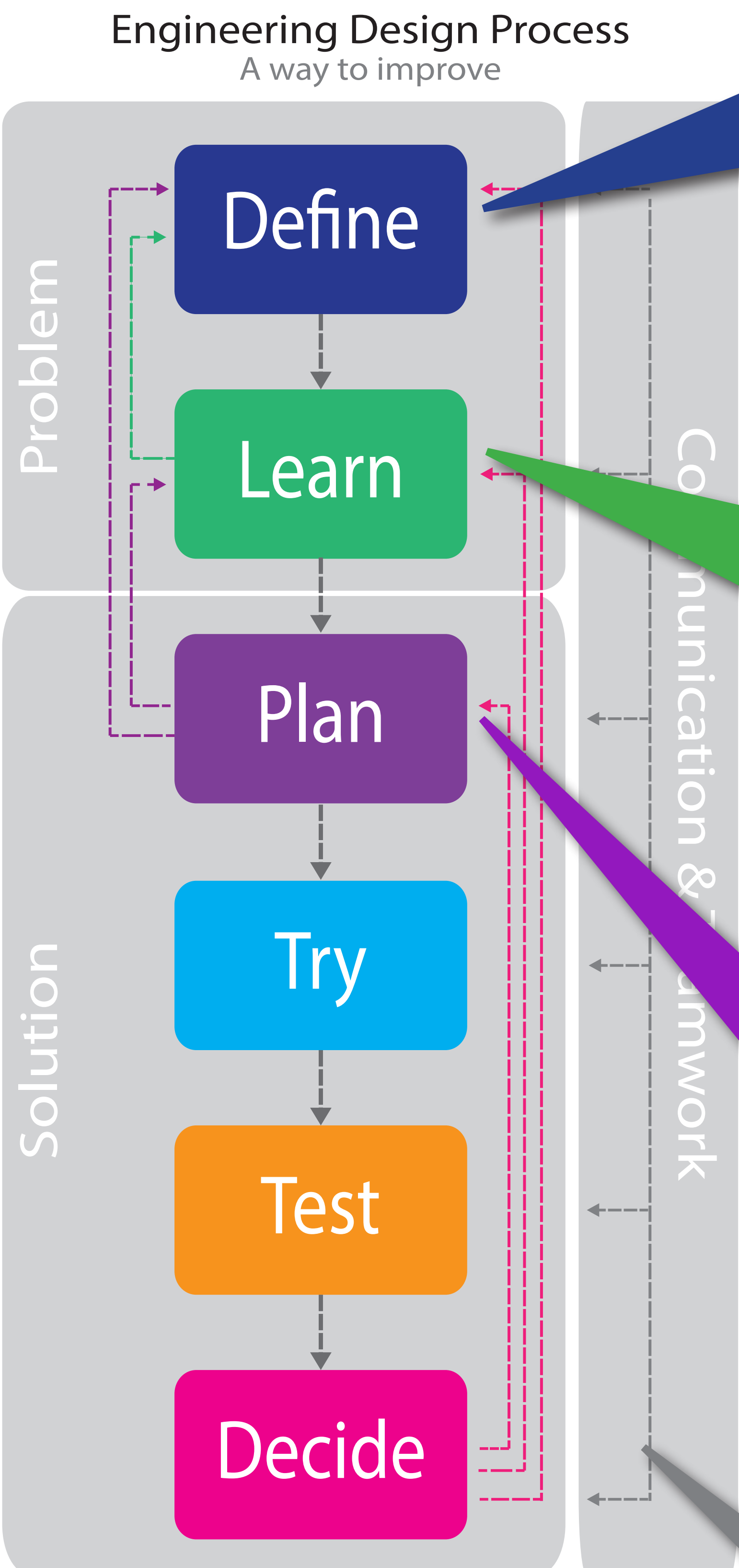
Overview: Engineering Design Process



DEFINE THE PROBLEM

- Who is the **client**?
- What does the client need?
- Why does the client need it?
- Who is the **end user**?
- Why might the end user want it?
- What are the **criteria** (requirements)and **constraints** (limits) of the solution?

Problem Scoping:
WHO needs **WHAT** because **WHY**

LEARN ABOUT THE PROBLEM

- What kind of background knowledge is needed?
    - What science/math knowledge will be needed?
    - What materials will be needed?
- What has already been done to solve the problem?
- What products fill a similar need?
- How should we measure success and improvement?

PLAN A SOLUTION

- Continue to specify the criteria/ constraints
- Generate ideas of possible solutions
- Develop multiple solution paths
- Consider **constraints, criteria**, and **trade-offs** (criteria that compete with one another)
- Choose a solution to try
- Develop plans (blueprints, schematics, cost sheets, storyboards, notebook pages, etc.)

COMMUNICATION

- Communicate the solution clearly and make sure it is easily understandable
- Use **evidence** to support why the client should use your solution

Overview: Engineering Design Process

TRY A SOLUTION

- Put the plan into action
- Consider risks and how to optimize work
- Use criteria/constraints and consider trade-offs from the problem/plan to build a **prototype** (a testable representation of a solution), **model**, or **product**

TEST A SOLUTION

- Consider testable questions or hypotheses
- Develop experiments or rubrics to determine if the solution is meeting the stated criteria, constraints, and needs
- Collect and analyze data

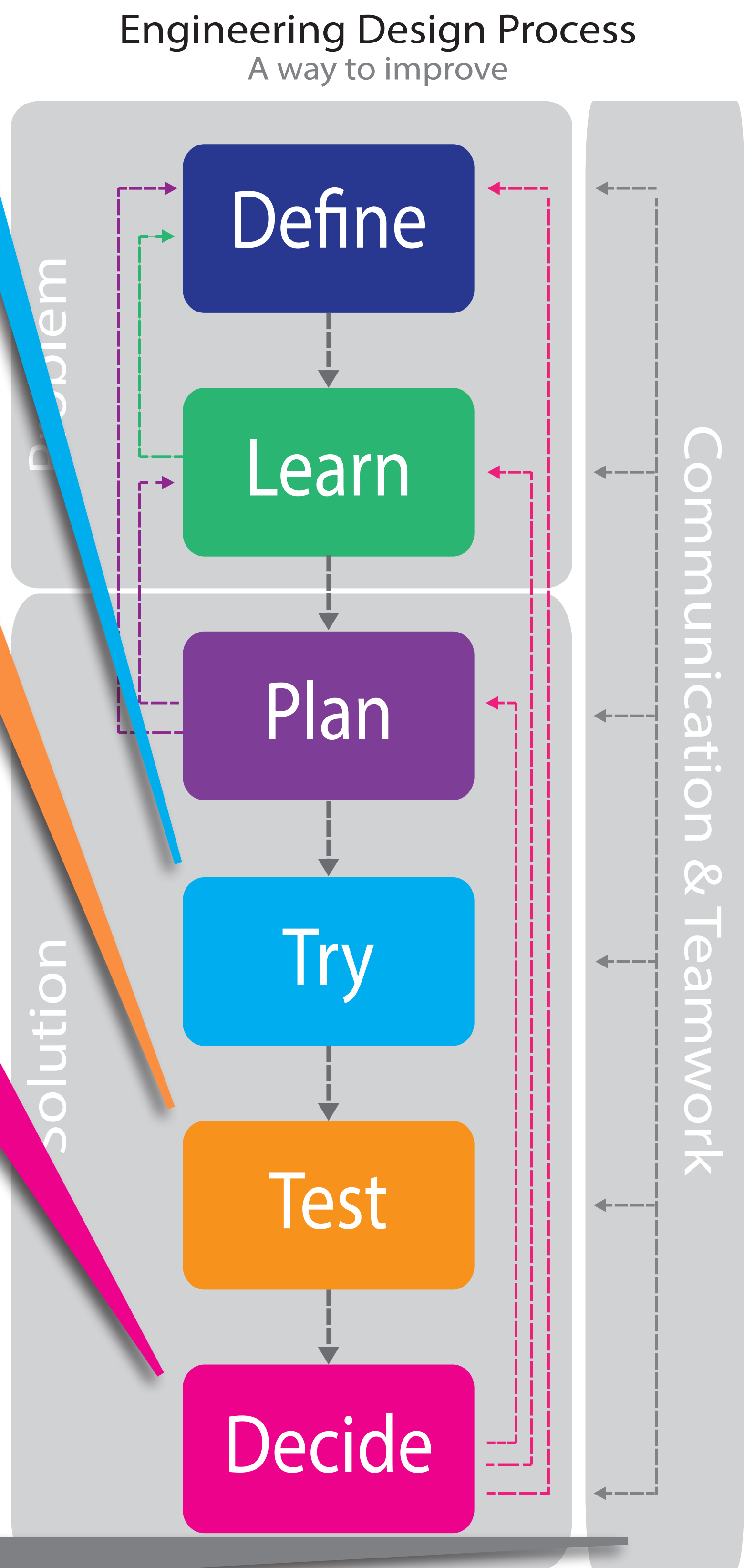
DECIDE IF THE SOLUTION IS GOOD ENOUGH

- Are users able to use the design to help with the problem?
- Does the design meet the criteria and constraints?
- How could the design be improved based on test results and feedback from the client/user?

Iterative nature of design: Always consider which step should be next!

TEAMWORK

- Discuss in teams how the solution meets the criteria and needs of the client
- Consider different viewpoints from each teammate



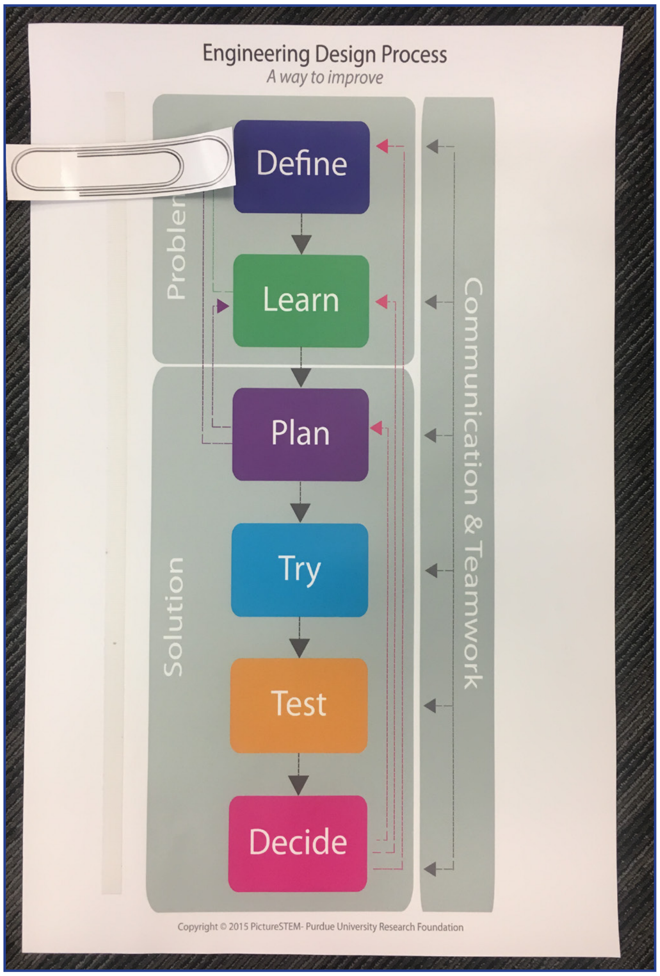
Overview: How to make EDP sliders

How to create the poster

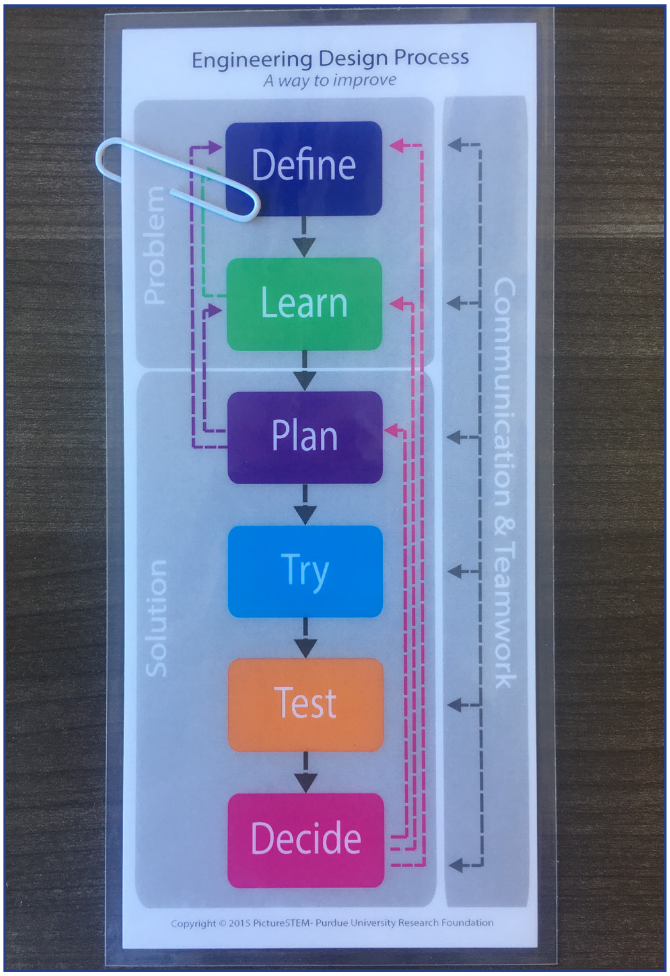
1. Download the high-quality PictureSTEM Slider Poster and the paper clip images from PictureSTEM.org.
2. Print the poster and the paper clip on poster-sized paper and cut to size. High-gloss or semi-gloss paper is the best choice.
3. Use self-sticking Velcro on the back of the paper clip and down the side of the poster so that the paper clip can be placed to point at all 6 sections of the slider.

How to create individual sliders

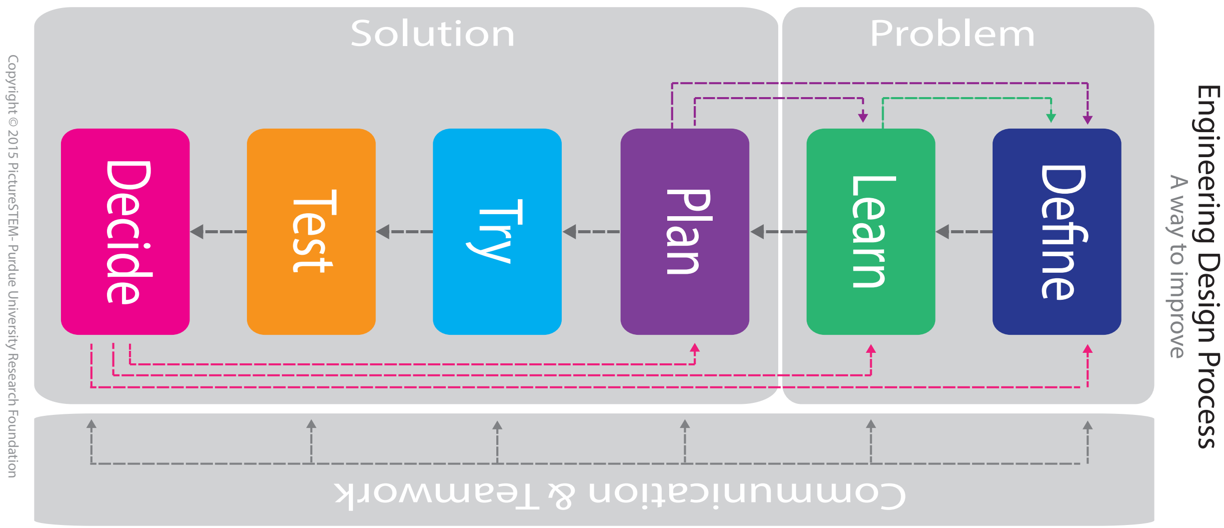
1. Print the sliders on the opposite page - enough for one slider per student in your class.
2. Cut the sliders apart.
3. Laminate the sliders individually.
4. Use a jumbo paper clip as the pointer for each slider.



Poster



Individual slider


Engineering Design Process
A way to improve
Problem
Solution
Define
Learn
Plan
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Communication & Teamwork
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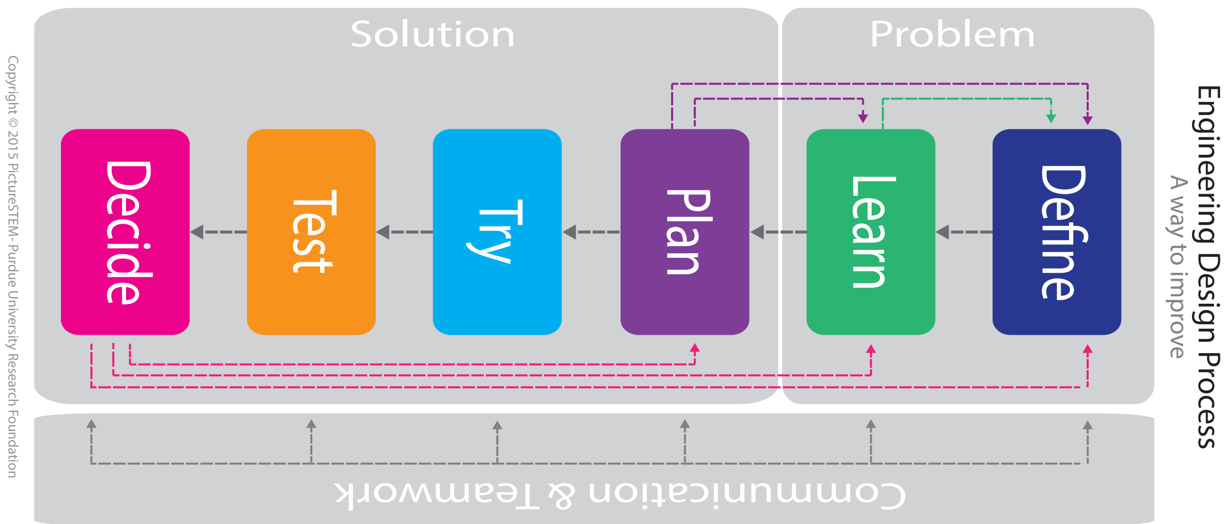
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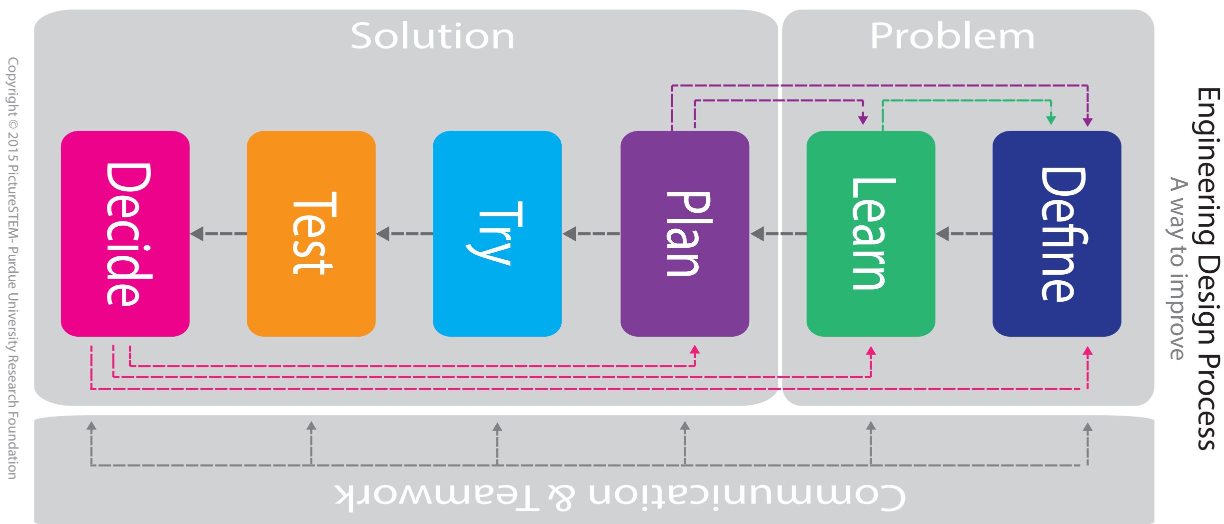
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Unit Overview

Grade Levels: Grades 6 - 9

Approximate Time Needed to Complete Unit: 2 weeks

Unit Summary:
Students are challenged to create an electronic expansion pack for the Sphero BOLT. Throughout the unit, students will explore how electricity works, power, green energy, programming, and material sourcing. The design must consider the environmental impact of their proposed prototype as well as the criteria and constraints from the client.

Subject Connections:

Science Connections	Technology and Engineering Connections	Mathematics Connections
Electricity, micro:bit, energy, voltage, resistance, current	Engineering design process, solution design, client	Ohm's law, cost calculations, electricity calculations

Standards:
Middle School

IDoE - Computer Science
- 6-8.CD.1: Design projects that combine hardware and software components to collect and exchange data. (E)
- 6-8.CD.4: Describe what distinguishes humans from machines, focusing on ways we can communicate, as well as ways in which computers use models of intelligent behavior (e.g., robot motion, speech and language understanding, computer vision).
- 6-8.PA.1: Design and iteratively develop programs that combine the following: sequencing, looping (included nested loops), conditionals (including compound conditionals), expressions, variables, functions, and parameters. (E)

IDoE - CTE: Engineering and Technology
- Core Standard 10: Students will identify, select, and use energy and power technologies.
- ETE-10.1: Analyze a variety of power and energy technology systems.
- ETE-10.2: Solve a simple power and energy challenge and create an efficient solution.
- ETE-10.3: Utilize appropriate designs, techniques, tools, and processes for energy and/or power systems.
- ETE-10.4: Design and construct simulations, models, and/or prototypes for energy and/or power systems.

Next Generation Science Standards
- MS-ETS1-1: Define criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-PS1-3: Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.
- MS-PS2-3: Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.
- MS-PS4-1: Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.
- MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

ITEEA: Standards for Technological and Engineering Literacy
- STEL-1J: Develop innovative products and systems that solve problems and extend capabilities based on individual or collaborative needs and wants.
- STEL-1M: Apply creative problem-solving strategies to the improvement of existing devices or processes or the development of new approaches.
- STEL-2O: Create an open-loop system that has no feedback path and requires human intervention.
- STEL-2P: Create a closed-loop system that has a feedback path and requires no human intervention.
- STEL-2S: Defend decisions related to a design problem.
- STEL-3F: Apply a product, system, or process developed for one setting to another setting.
- STEL-4M: Devise a strategy for reducing, reusing, and recycling waste caused from the creation and use of technology.
- STEL-4N: Analyze examples of technologies that have changed the way people think, interact, and communicate.
- STEL-7R: Refine design solutions to address criteria and constraints.
- STEL-7U: Evaluate the strengths and weaknesses of different design solutions.
- STEL-8J: Use devices to control technological systems.

High School
IDoE - CTE: Engineering and Technology
- DE-6.1: Create and test circuits using circuit design software.
- DE-6.2: Determine values associated with resistence, voltage, current and continuity using a digital multi-meter.
- DE-6.3: Demonstrate successful soldering and desoldering techniques.
- DE-6.4: Demonstrate breadboarding techniques to build a working circuit.
- DE-8.8: Investigate types, functions, and power requirements or integrated circuits (logic gates).
- Core Standard 10: Students will identify, select, and use energy and power technologies.
- ETE-10.1: Analyze a variety of power and energy technology systems.
- ETE-10.2: Solve a simple power and energy challenge and create an efficient solution.
- ETE-10.3: Utilize appropriate designs, techniques, tools, and processes for energy and/or power systems.
- ETE-10.4: Design and construct simulations, models, and/or prototypes for energy and/or power

systems.

IDoE - Integrated Chemistry and Physics
- HS-ICP3-5: Gather data to build a model to describe and explain the flow of current through series and parallel electric circuits.

Next Generation Science Standards
- HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and asethetics as well as possible social, cultural, and environmental impacts.

ITEEA: Standards for Technological and Engineering Literacy
- STEL-1N: Explain how the workd around them guides technological development and enigneering design.
- STEL-1Q: Conduct research to inform intentional inventions and innovations that address specific needs and wants.
- STEL-1R: Develop a plan that incorporates knowledge from science, mathematics, and other disciplines to design or imporve a technological product or system.
- STEL-2T: Demonstrate the use of conceptual, graphical, virtual, mathematical, and physical modeling to identify conflicting considerations before the entire system is developed and to aid in design decision making.
- STEL-2X: Cite examples of the criteria and constraints of a product or system and how they affect final design.
- STEL-4P: Evaluate ways that technology can impact individuals, society, and the environment.
- STEL-4R: Assess a technology that minimizes resource use and resulting waste to achieve a goal.
- STEL-6F: Relate how technological development has been evolutionary, often the result of a series of refinements to basic inventions or technological knowledge.

Master Materials List

	Unit Materials	Lesson Where Material is Used
Per Classroom	• EDP Poster • Chart paper • BOLT Power Pack Educator Guide 2022, page 13 (BOLT components diagram) • (8) micro:bits with battery packs and batteries • Deconstructed cell phone • External ultrasonic sensor • External light sensor • DC motor • (2) EMF blocking fabric ~0.25 yard piece • Cardboard ~8.5”x11” • Flashlight • Dark/heavy cloth • Light colored/light cloth • Paper cup • Dark plastic or ceramic cup	1, 2, 3, 4, 5, 6, 7, 8, 9, 10 1 3 3 3 3 3 3 3 3 3 3 3 3 3
Per Group (assume 3 students per group)	• Sphero Bolt • Disposable Plastic Cup • Tape • Marker • White computer paper • breadboard • resistors • LEDs • transistors • capacitors • micro:bit • Battery pack • Breadboard adaptor • Servo • Jumper wires	2 2 2 2 2 4,6 4 4 4 4 6 6 6 6 6
Per Student	• EDP slider w/ jumbo paperclip • Laptop or equivalent device • Engineering notebook	1, 2, 3, 4, 5, 6, 7, 8, 9, 10 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Lesson Summaries

Lesson 1: Define it
Students are introduced to the Engineering Challenge by their client which will serve as the context within which students can learn about microelectronics. Students will learn about the Engineering Design Process and then take part in iterative class and group discussions to identify criteria, constraints, and knowledge gaps needed to successfully solve the client's challenge.

Lesson 2: Drive it
Students will learn about the Sphero BOLT by operating it and learning the different available functions. Teams will move the Sphero in different ways, change its color and speed, and draw their names on a sheet of paper using the robot. Students will also learn how to block code and program the Sphero BOLT to make shapes without constant human control.

Lesson 3: Break it down
Students investigate microelectronics components (ME) that simulate current Sphero components. Students also investigate ME components, based on the cell phone, that they could use for their electronic expansion pack. Students will rotate through stations with physical devices that mimic or demonstrate the capabilities of Sphero and other potential components using a microcontroller and accessories. Some stations will display an aspect of the physical science principles behind the operation of the device via a video or graphic. Students experiment with the device to discover the constraints around operating such devices.

Lesson 4: Power it
The client provides a power constraint for the electronic expansion pack design. Students will investigate Ohms law to test their design for adherence to the constraint. Students will read basic circuit schematics and relate them to actual components. Students will build simple circuits.

Lesson 5: Conserve it
Students learn about and discuss sources of electricity. They will research renewable and nonrenewable sources of energy and the advantages and disadvantages of each. This will be important as environmental considerations were listed in the client letter.

Lesson 6: Program it
Students use the micro:bit and breadboard to code a servo. Using their basic breadboarding skills that were taught to them, students will properly connect wires to a controller and use be taught basic programming to code the servo to function in some way.

Lesson 7: Plan it
Now that students have learned about the Sphero, electricity, block coding, and renewable energy, they are ready to develop their ideas into a solution to the engineering design challenge. Students will work individually and in teams to brainstorm, create mind maps, and sketch their ideas. They will converse and decide on one best electronic expansion pack per team prior to the end of class.

Lesson 8: Build it
Students will build their product designs within their teams. Depending on the grade level being taught, these builds can be true designs or simply representations of their product. Students will calculate the cost of their design based on the materials used to create it.

Lesson 9: Test it
Now that students have built a model or prototype of their design, they are going to test it out. Students will evaluate their own products based on a provided decision matrix. The decision matrix lists four factors to consider when presenting their design to the client. After evaluating their own designs, teams will brainstorm how they can improve their score, therefore improving their product.

Lesson 10: Recommend it
In this lesson, students will report out their group findings to provide a holistic recommendation to the client as a class. Students will prepare presentations as a team to share their design with the class. Students will review one another using the decision matrix prior to providing a final recommendation to the client

Unit Planner

Lesson	Time Needed	Objectives	Duplication Master
1. Define it	One 50-minute lesson	• Identify the problem from a client. • Explain the differences and similarities between the engineering design process and scientific inquiry. • Identify background knowledge needed to develop a solution. • Explain the criteria and constraints.	1.A Content Pre-Assessment 1.B Problem Scoping Prompts 1.C EDP and Scientific Inquiry Comparison 1.D Client Letter
2. Drive it	One 50-minute lesson	• Effectively describe how to perform basic operations and coding of Sphero units. • Understand the basic components of a Sphero.	2.A Client Memo 1 2.B Activity 1: Human Control 2.C Activity 2: Sphero Draw 2.D Activity 3: Sphero Draw Challenge 2.E Activity 4: Sphero Block Coding 2.F Sphero Evaluation Sheet
3. Break it down	Two 50-minute lessons	• Name and describe in detail each of the Sphero components • Identify the capabilities of micro:bits add-on components.	3.A Component Stations
4. Power it	Two 50-minute lessons	• Use Ohms Law to calculate voltage, current, and resistance • Assemble electronic and microelectronic circuits to create a desired objective.	4.A Client Memo 2 4.B Simple Circuit 4.C Simple Circuit Breadboard 4.D Simple Circuit 2 – Multimeter 4.F Ohm's Law Triangle
5. Preserve it	One 50-minute lesson	• Distinguish between renewable and non-renewable energy sources • Explain the impact that non-renewable energy has on the environment	5.A Types of Energy

Lesson	Time Needed	Objectives	Duplication Master
6. Program it	One 50-minute lesson	• Utilize a microbit to construct a circuit.	6.A Servo Wiring 6.B Servo Code
7. Plan it	One 50-minute lesson	• Design solutions to an engineering design challenge • Create a mind map • Brainstorm as a team • Defend design decisions	7.A Client Memo 3 7.B Example Mind Map 7.C Brainstorming Worksheet 7.D Design Sketching
8. Build it	One 50-minute lesson	• Create a model that represents their design • Work together within a design team • Perform cost calculations	8.A Material Cost List
9. Test it	One 50-minute lesson	• Test a prototype • Evaluate a prototype based on provided criteria	9.A Decision Matrix Directions 9.B Decision Matrix Activity
10. Recommend it	Two 50-minute lessons	• Communicate science, technology, engineering, and mathematics ideas by giving presentations • Use evidence-based reasoning to support their engineering decisions	10.A Client Memo 4 10.B Client Communication Requirements 10.C Decision Matrix Directions 10.D Decision Matrix Activity 10.E Client Memo 5 10.F Content Post-Assessment

Unit Background

Introduction

This background defines important terms and concepts used within this unit.

Teamwork

This unit will have students working in teams. Effective teamwork is essential in this unit, just like in engineering. Students should be teamed strategically and may or may not be assigned jobs within their team. When forming student teams, consider academic, language, and social needs. In place of strategic teaming, a random teaming can be substituted. Students will work in these teams of 3 or 4 throughout the unit. Effective teamwork is essential in this unit as well as in engineering in general.

Career Connections

Students will be introduced to new STEM content potentially for the first time. There are many career opportunities that align with the content in this unit. Please plan to highlight these as you see fit and encourage students to think about how these topics align with their personal and future interests.

Engineering Design Process

NOTE: If students are familiar with the engineering design process (EDP) before beginning the unit, the teacher can skip this (EDP) introduction.

The engineering design process (EDP) is an iterative, systematic process used to guide the development of solutions to engineering problems. There is no single engineering design process, just like there is no one scientific method. However, the various engineering design processes have similar components. The engineering design process (EDP) involves understanding the problem, learning background information necessary to solve the problem, planning, trying, testing the solution, making changes based on the tests, and communicating their ideas. Students will use an engineering design process slider throughout the unit to help them understand where they are in the design process. For more information about the steps of the engineering design process presented in this unit, see the front matter section at the front of the unit.

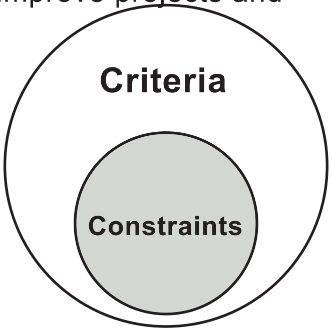
Some common misconceptions about engineering

- Engineers do not have to learn anything new when they are working on a project. **In reality**: Engineers need to continually learn throughout their lives.
- Engineers come up with solutions that are just “good enough” and do not take risks. **In reality**: Engineers strive to create the best solution possible through optimization. It is normal to experience failure when solving engineering problems.
- Engineers work alone to solve a design problem. **In reality**: Engineers collaborate with people in different disciplines and fields to best solve a problem. Engineering problems often require a wide range of content knowledge.

Some common misconceptions about the EDP

- The engineering design process is linear, and you never need to go back to previous phases. **In reality**: The EDP is a cyclical process that requires many iterations.

- Once the project is done, it is considered complete and not revisited. **In reality**: The engineering design process is never really "done" and it is revisited so engineers can improve projects and make changes.



Criteria and Constraints

One difficulty that students might experience is distinguishing between criteria and constraints. Criteria are the things required for a successful design, or the goals of the designed solutions. They help engineers decide whether the solution has solved the problem. Another way of thinking about criteria are that they are anything that the client and the engineers will use to judge the quality of a solution. Constraints are a specific type of criteria; they are those criteria that limit design possibilities, or the ways that problem can be solved. If constraints are not met, the design solution is by default not a viable solution to the problem. The relationship between criteria and constraints is represented in the figure. It may be helpful to post the definitions with the figure somewhere in the classroom for future reference.

Problem Scoping

Define the problem and learn about the problem combine to make Problem Scoping. In this stage, students will be first introduced to the engineering problem through a client letter and then be given a chance to ask questions to the client to receive more information about the problem. The problem statements given in the client memos purposefully do not provide all the information necessary to solve the problem. Students are tasked with generating questions about the problem to try to fill in this missing information. Based on all information from the client, students will then define the problem in terms of: what the problem is and why it is important, who are the client and end users, what are the criteria and constraints, and what other information they may need to learn about in order to solve the problem. This process of generating ideas and questions for the client is an important skill on its own both in engineering and in other fields, but it also helps to ensure that the students fully understand the problem and their task in the engineering design challenge.

Solution Generation

The Solution Generation section of the engineering design process includes plan the solution, try out the plan of the solution, test the solution, and decide whether the solution is good enough. When engineers are generating solutions, they will use iteration to continually improve their solution, reflect back on the problem definition and what they have learned about the problem, and consider criteria, constraints, and trade-offs. Trade-offs involve having to make compromises about which criteria to emphasize because they compete with one another in terms of making the solution effective. For example, cost could be a trade-off for durability.

Engineering Notebook

Throughout the unit students will be recording information in an engineering notebook, and they will need the notebook at the start of the unit. The engineering notebook is set of documents which includes writing prompts, black space to take notes or upload pictures of work, and copies of the duplication masters that are listed in each lesson. The engineering notebook can be offered electronically or on paper and can be adapted to your classroom needs. Students' engineering notebooks will support their communication of ideas and should be used consistently throughout the unit.

Microelectronics

Microelectronics (ME) can be defined as the design, manufacture, and use of microchips and integrated circuits. Students will use microelectronics in this unit as a tool to make board games more engaging.

What are microelectronics? The microchips are the key that makes microelectronics work. The microchips are made from small pieces of a semiconductor material, which is usually silicon. Semiconductors are special because they can allow electrons to move through them or not, depending on how they are used. Engineers take advantage of silicon's semiconductor property to design circuits that control how electrons move through a microchip. There are four main types of microchips: memory chips that store information, logic chips that process information, application-specific integrated chips that perform repetitive tasks, and system-on-a-chip chips that combine multiple circuits into a single chip.

When you use the micro:bit in this unit, you can see its microchips on the back. One is the processor, or the brains, of the micro:bit; the processor reads and completes the tasks in the code. The other is the USB cable chip, which lets the micro:bit communicate with the computer. See descriptions here: https://microbit.org/get-started/features/overview/. This link shows an image of the inside of a chip similar to the processor in the micro:bit: https://en.wikipedia.org/wiki/ARM_Cortex-M#/media/File:STM32F100C4T6B-HD.jpg

How are microelectronics made? This is a highly technical process, but broadly, it works like this: Sand is refined into pure silicon that is grown into crystals and then cut into thin circular wafers. Fabrication companies design the circuits for a microchip's purpose and etch that circuitry onto the silicon. They then cut each circuit out of the wafer and package it into a case that protects it and lets it function with other electronic components, like speakers, sensors, motors, and more. The circuits on a chip can contain thousands to billions of tiny components (primarily transistors but can include other components, too). Because the circuits are so small, they must be manufactured in a clean room. A piece of dust is big when compared to the size of a transistor on a chip! For reference, a low-end iPhone in 2023 has a microchip that is a system-on-a-chip with 15 billion transistors on it and is roughly one square centimeter in size.

Once the microchips are designed and manufactured, they are sent to other sites where they are integrated into devices like the micro:bit, your phone, your school bus, your dishwasher, and your toys.

Why are microelectronics important? Microelectronics are everywhere. They help make electronic devices cheaper, faster, and more energy efficient. Without them, many things we take for granted would stop working. Many high tech, high paying, and in-demand jobs require knowledge of microelectronics.

You do not need to be familiar with ME content to teach this unit however this list of resources may help

you feel more prepared to talk about ME-related topics with your students:
[INSERT LINKS]

Vocabulary

Students will be introduced to many new microelectronic and engineering vocabulary terms throughout the unit. It may be helpful to create a vocabulary section in their notebook with term definition and memory clue. Additionally, the class could maintain a word wall.

Term	Definition
problem scoping	defining the problem and learning about the problem
criteria	features of the solution that the client wants
constraints	a specific type of criteria; the criteria that limit design possibilities or ways that the problem can be solved
evidence-based reasoning	supporting a solution or recommendation with scientific analysis and/or data
design matrix	a tool used to compare, assess, and prioritize a set of options based on weighted criteria
client	the person or company who requests your help to solve a problem
end user	anyone who will use the solution you provide to the client's problem
microelectronics	the design, manufacture, and use of microchips and microcircuits
microchip	computer chip or integrated circuit that is used for processing and storing information in electronic devices
coding	using a computer programming language to write a set of instructions that will be executed by a microelectronic device; also called programming

LESSON ONE:

Lesson Objectives

Students will be able to:

- Identify the problem from a client.
- Explain the differences and similarities between the engineering design process and scientific inquiry.
- Identify background knowledge needed to develop a solution.
- Explain the criteria and constraints.

Materials

Per classroom

- EDP Poster
- Chart paper

Per team

- None

Per student

- EDP slider w/ jumbo paperclip
- Laptop or equivalent device
- Engineering notebook

Time Required

One 50-minute lesson

Standards Addressed

NGSS:

- MS-ETS1-1
- HS ETS1-1

Key Terms

- client
- engineering design process
- criteria
- constraints
- microelectronics

Lesson Summary

Students are introduced to the Engineering Challenge by their client which will serve as the context within which students can learn about microelectronics. Students will learn about the Engineering Design Process and then take part in iterative class and group discussions to identify criteria, constraints, and knowledge gaps needed to successfully solve the client's challenge.

Background

Teacher Background

Teamwork

The teams will operate as consulting engineers with each team working together to design an electronic expansion pack for the Sphero BOLT.

Engineering Design Process

In this lesson, students will be in the Problem Scoping section of the engineering design process, specifically on the "Define" step.

Before the Activity

- Assemble the Engineering Design Process Sliders and post the EDP poster in the classroom (see the front matter for how to assemble them). If your students do not want to use the sliders, simply hanging the poster achieves the same result. Make sure you and your students can refer to the EDP sliders and/or poster throughout the unit.
- Determine student teams of three or four. These teams should be their teams throughout the rest of the unit.
- Print and make copies of the following worksheets in the labeled amounts:
  - (1 per student) 1.A Content Pre-Assessment, 1.D Client Letter
  - (1 per group) 1.C EDP and Scientific Inquiry
- (Optional) Prepare the pre-assessment activity in the form of a survey, kahoot, etc. using the questions on 1.A Content Pre-Assessment

Classroom Instruction

Introduction

1. **Complete the content pre-assessment activity.** The students

will participate in a more formal pre-assessment to assess their current level of knowledge and understanding regarding the topics of electricity, the Sphero, a micro:bit, microelectronics, and the engineering design process. Using the questions on the 1.A Content Pre-Assessment, distribute hard copies or have students respond to a digital version of the survey. Make sure to tell students that this is just to assess any prior knowledge, so it is okay to not know the answers.

- NOTE: Students completing the pre-assessment online may attempt to look up answers. Minimize this as much as possible.

2. **Review prior knowledge.** Lead a discussion with the class in which students are able to share their prior knowledge on the topics of engineering, electricity, block coding, and microelectronics. Prompts may include the following: *What do engineers do? What kinds of industries do engineers work in? What is a Sphero? How does electricity work? How do you program a micro:bit?*
3. **Set up engineering notebooks. Say:** *Engineers use notebooks to document their design process and keep notes. We will also be using Engineering Notebooks throughout our engineering challenge. Each day, you'll use the notebooks to take notes and record what you are learning. In addition, there are questions that you'll be asked to answer.* NOTE: You can have your students enter in their notebooks in two different colors – one for thoughts and prompts that are individual and one for thoughts and prompts that they discuss in their teams. This will help both you assess, and the students recognize, where ideas came from. You also may want to have students start a Table of Contents page.
4. **Complete problem scoping section 1.** Direct students to the 1.B Problem Scoping Prompts in their engineering notebooks. Have students individually answer the prompts from section 1. Make sure to let them know that it is okay if they do not know very much about engineers or engineering – just have them answer these questions to the best of their ability.
5. **Form teams.** After students have finished the prompts, explain that for the rest of the unit they will start the day with a review of the engineering design process and then look at a specific problem that will require the use of that process. Explain that students will work in small teams to solve a problem brought to them by the client. Divide students into teams of 3 or 4.

Assessments

Pre-Activity Assessment

Assess students' prior knowledge by listening to their responses to 1.B Problem Scoping Prompts. Use students' answers to 1.A Content Pre-Assessment as baseline data about the students' current level of understanding and background knowledge.

Activity Embedded Assessment

Observe students' discussions and written responses to 1.B Problem Scoping Prompts. Check students' brainstorming lists to see if they can identify the content they will be expected to master by the end of the unit.

Post-Activity Assessment

Use the 1.E Problem Scoping Section 3 Key to evaluate students' answers to the notebook prompts.

Duplication Masters
- 1.A Content Pre-Assessment
- 1.B Problem Scoping Prompts
- 1.C EDP and Scientific Inquiry Comparison
- 1.D Client Letter

Educator Resources
- 1.E Content Pre-Assessment Key
- 1.F Problem Scoping Section 3 Key

Activity

6. **Discuss engineers and engineering.** Allow students to share their answers from 1.B Problem Scoping Prompts section 1. Define engineers and engineering and take some notes for students to enter in their notebooks. As a class create a list of the different types of engineering and have students brainstorm careers that may fall within each type of engineering in their notebooks. Explain that the problem they will be solving falls under the category of engineering design and draws on electronics to understand the context and generate a solution.

7. **Introduce the Engineering Design Process.** Display the Engineering Design Process poster and pass out individual EDP Sliders and a paper clip to each student. **Say:** *Engineers use an engineering design process, along with mathematics, science, and creativity, to understand a problem and come up with a solution. Since we are working as engineers during this unit, we will be using this engineering design process as a guide while we come up with a solution for our engineering problem.* Go through the EDP Slider and ask the students what they think each stage involves. Be sure to clarify any misconceptions and elaborate where needed. There is a detailed description of the EDP Slider in the front matter of the unit. **Ask:** *Based on what we have discussed so far, where do you think we are in the engineering design process?* **(Define).**

8. **Compare the Engineering Design Process and Scientific Inquiry.** Have students individually examine 1.C EDP and Scientific Inquiry Comparison then, in their teams, discuss the differences and similarities between the two methods. Remind them to keep track of the discussion in their engineering notebooks to share back with the class later. Have a class discussion allowing teams to share what they noticed about the two methods.
   - NOTE: If you don't have time, you can skip comparing the two processes.

9. **Introduce the problem.** Allow students time to read copies of the 1.D Client Letter. Encourage them to enter in their notebooks as they read to keep track of important information. Give students time to discuss in small teams what information they read in the letter. **Ask:** *What is the challenge? What are some possible constraints and criteria?*

10. **Identify the problem from the client.** Have the students reread

the letter, if necessary, to identify the problem and enter it in their notebooks.

11. **Identify required information.** Have students work together to brainstorm a list of "required information" in order to help the client with their request. Encourage them to highlight/underline the things on their list they already know. Then as a class create an anchor chart that will be revisited throughout the unit. As students learn information you can check content off of the anchor chart or add to it if they think of some other information that they will need to help the client.

12. **Complete problem scoping section 2.** After reading the letter, direct students to respond to section 2 of the 1.B Problem Scoping Prompts in their notebooks. They can do this individually or in teams.

13. **Complete problem scoping section 3.** After students have completed the section 2 prompt, direct students to section 3 of 1.B Problem Scoping Prompts. They can do this individually or in teams.

Closure

14. **Revisit the problem.** Give the students a chance to revise their list of questions or required information they composed for the engineering challenge.

15. **Discuss the engineering design process. Ask:** *Which phase of the engineering design process did we focus on related to our challenge today? Why is this important?* Ex: Students need to understand the root problem from the perspective of the client and other stakeholders before attempting a solution.

Name____ Date_______________ Period __________

1.A Content Pre-Assessment

1. What is a robot?

2. What are the contents of the Sphero BOLT?

3. Write the equation for Ohm's Law.

4. What does resistance mean in the context of electricity?

5. Briefly explain how electricity works.

6. Define the term "renewable energy".

7. What does the term "microelectronics" mean?

8. Provide two examples of what a micro:bit can do.

9. How are microelectronics used in engineering and technology?

10. What jobs would you be interested in that use microelectronics? Provide one example of how microelectronics is used in that job.

Name____ Date_______________ Period __________

1.B Problem Scoping Prompts

Section 1:

Directions: Please answer the following questions.

1. What do engineers do?

2. How do engineers solve problems?

Section 2:

Directions: Please answer the question after hearing about the engineering design challenge.

3. What questions do you want to ask the client?

Name____ Date_______________ Period __________

1.B Problem Scoping Prompts

Section 3:

Directions: Please answer these questions after you have been able to ask questions about the challenge. First, complete each prompt on your own. Then write your revised answer (if different) to the prompt, based on the discussion with your team. You may use a different color writing utensil or font color to distinguish your answer and how it changed after talking with teammates.

4. The client is:

5. The client's problem is:

6. The problem is important to solve because:

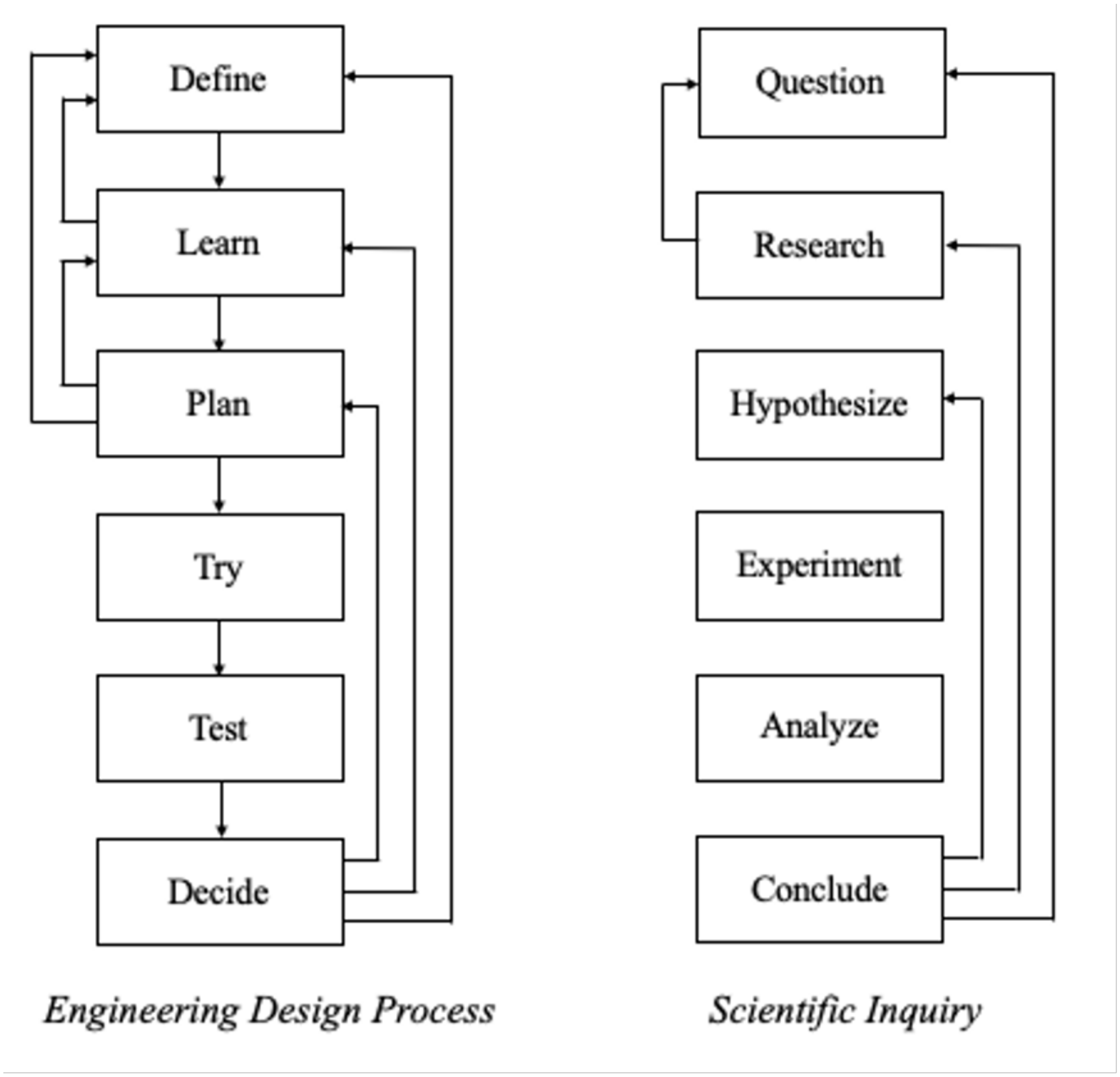
7. The end-users are:

8. An effective solution for the client will meet the following criteria:

9. The constraints (or the limits) of the solution are:

10. Think about the problem of carbon emissions. In terms of designing a method to combat this issue, what are at least 2 things you need to learn in order to make an evidence-based recommendation? Make sure to consider all important aspects of the problem. Be specific.

1.C EDP and Scientific Inquiry Comparison



1.D Client Letter

Dear Engineers,

Science, technology, engineering, and mathematics (STEM) are subjects that can often be difficult to learn. However, understanding these complex topics is important as they are the foundation for technology advancements in society. Using toys to help convey these concepts can be highly beneficial to learners.

Sphero is a company that makes STEM toys to help students engage in these subjects. They offer a variety of products and kits that can be used at school or home to make learning STEM a fun experience. One of their devices, called BOLT, is a programmable robot sphere that focuses on engineering and coding concepts.

My company works alongside the designers that create STEM toys to help develop their products. This is important for teachers who wish to use these tools in their classroom to supplement their existing lesson plans, or for people who wish to learn more about microelectronics on their own. However, we are often limited by a strict budget, which specific microelectronic components the designers can use, and environmental considerations for electricity. I want to enlist your help to assist us in our collaboration with the Sphero company and their BOLT robot by providing other electronics-based items to sell on the side. We want your ideas for an electronic expansion pack for the Sphero.

Please use the engineering design process, science and mathematics knowledge, and your ingenuity to make an evidence-based recommendation for us. Please include this recommendation in your final report so we know why you have come to your conclusion. Note that this recommendation must be reliable, cost-effective, ethical, and demonstrate the use of scientific reasoning. We look forward to reading your report and implementing your result.

Sincerely,

Mike Rowbit

Mike Rowbit
Engineer
BLEEEP (BLossom Engineering Electronic Expansion Packs)

1.E Content Pre-Assessment Key

1. What is a robot?
   Answers will vary, and it is the teacher's disrection what should receive credit.

2. What are the contents of the Sphero BOLT?
   The Sphero BOLT has LEDs, an IMU, encoders, a circuit board, batteries, processor, and motors.

3. Write the equation for Ohm's Law.
   V = I * R or Voltage = Current * Resistance

4. What does resistance mean in the context of electricity?
   Resistance is an opposition to the flow of current in an electrical circuit.

5. Briefly explain how electricity works.
   Electricity is the flow of electrical charge. It is generated through the movement or accumulation of electrons.

6. Define the term "renewable energy".
   Renewable energy is energy that is generated from renewable resources, or resources that are naturally replenished on a human timescale.

7. What does the term "microelectronics" mean?
   Student answers may vary, but the formal definition of microelectronics is the design, manufacture, and use of microchips.

8. Provide two examples of what a micro:bit can do.
   Answers will vary, but correct answers include telling time, counting steps, programming a task, etc.

9. How are microelectronics used in engineering and technology?
   There are many answers to this question, but examples include computers, electric vehicles, or circuitry.

10. What jobs would you be interested in that use microelectronics? Provide one example of how microelectronics is used in that job.
    Students answers will vary based on interest. Credit may be given as long as at least one job example is provided with their logic behind how that job uses microelectronics.

1.F Problem Scoping Section 3 Key

Section 3:

4. The client is:
   Mike Rowbit at BLEEP.

5. The client's problem is:
   Science, technology, engineering, and mathematics (STEM) are subjects that can often be difficult to learn.

6. The problem is important to solve because:
   Understanding STEM topics are important as they are the foundation for technology advancements in society.

7. The end-users are:
   Teachers who wish to use these tools in their classroom, or people who wish to learn more about microelectronics on their own.

8. An effective solution for the client will meet the following criteria:
   Reliable, cost-effective, ethical, and demonstrate the use of scientific reasoning.

9. The constraints (or the limits) of the solution are:
   A strict budget and which specific microelectronic components the designers can use.

10. Think about the problem of carbon emissions. In terms of designing a method to combat this issue, what are at least 2 things you need to learn in order to make an evidence-based recommendation? Make sure to consider all important aspects of the problem. Be specific.
    Answers will vary. Potential ideas include what microelectronic components are available, how the Sphero BOLT works, how electricity works, what the cost constraints are, etc.

    Note that Client Memo 1 (in Lesson 2) mentions that it is in response to the students questions concerning how the BOLT works and what it is. This should be included in your classroom discussion.

LESSON TWO:

Lesson Objectives

Students will be able to:

- Describe how to perform basic operations and coding of Sphero units.
- Understand the basic components of a Sphero.

Materials

Per classroom

- EDP Poster

Per team

- Sphero Bolt
- Disposable Plastic Cup
- Tape
- Marker
- White computer paper

Per student

- EDP slider and paperclip
- Laptop or equivalent device
- Engineering notebook

Time Required

One 50-minute lesson

Standards Addressed

Middle School

- STEL 2:O
- STEL 2:P
- STEL 3:F
- STEL 8:J
- 6-8.CD.1
- 6-8.CD.4
- 6-8.PA.1

High School

- STEL 1:N
- STEL 1:Q
- STEL 2:X

Key Terms

- draw
- block coding
- control

Lesson Summary

Students will learn about the Sphero BOLT by operating it and learning the different available functions. Teams will move the Sphero in different ways, change its color and speed, and draw their names on a sheet of paper using the robot. Students will also learn how to block code and program the Sphero BOLT to make shapes without constant human control.

Background

Teacher Background

Sphero Functions

Teachers will need to understand how the Sphero BOLT works and its various functions. The following resource should be reviewed: https://edu.sphero.com/Sphero/home

Introduction to Block Coding

Teachers will need to understand how to block code prior to teaching this lesson. The following resource should be reviewed: https://edu.sphero.com/cwists/preview/21499x

Engineering Design Process

Students will be in the Learn stage of the EDP during this lesson.

Before the Activity

Download the Sphero app and ensure that all students have this app on their personal devices.

Classroom Instruction

Introduction

1. **Read the client memo.** Have students read 2.A Client Memo 1 and discuss the task of this lesson as a class.
    - NOTE: Please note that this letter explicitly mentions that it is in response to the questions students had about the Sphero. If this was not discussed in the previous lesson, this wording should be changed prior to distribution.
2. **Tie in the engineering problem. Ask:** *What is our engineering design problem?* Students may need to revisit the original client letter to remind themselves of the engineering design challenge.
3. **Identify where they are in the engineering design process**

(Learn). Say: *So far, we have defined the problem with help from our client.* Point out the "Problem" block of the Engineering Design Process (EDP) poster and have students look at their EDP sliders. Say: Before we can start designing solutions, we need more information. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.

4. **Identify what students need to learn about. Say:** *In the previous lesson, you brainstormed what we need to learn about.* **Ask:** *What were some of those concepts that we need to learn?* Remind students to refer to their notes from the previous lesson. Teachers may encourage students to add to the class anchor chart.

Activity

5. **Introduce the topic for the day. Say:** *To solve our engineering design challenge, we will need to learn more about the Sphero BOLT. Today, we will be working through different activities to teach us about its capabilities.*

6. **Separate into pre-determined design teams.** Have students get together with their partner or group members. Provide each group with their Sphero.

7. **Hand out Duplication Masters 2.B, 2.C, 2.D, 2.E, and 2.F to each student. Say:** *You can now learn about the Sphero BOLT and its functions. While you are operating the Sphero BOLT, fill out the questions about its capabilities and any ideas you have.*

8. **Allow design teams to work through all four activities.** The teacher may want to set boundaries for each group so that the Sphero BOLTs do not bump into each other or any objects in the room.

Closure

9. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us recommend other items to sell on the side? What can the Sphero BOLT do? What can the Sphero BOLT not do?* **Say:** *We will continue in the Learn stage during our next class.*

Assessment

Pre-Activity Assessment

Ask if students have ever seen or used a Sphero BOLT before. If they haven't, ask what they anticipate it will be able to do.

Activity Embedded Assessment

Have students fill out Duplication master 2.F Sphero BOLT Evaluation Sheet. Review their answers to determine if they understand how the Sphero BOLT functions and if they came up with any ideas on how it the tool.

Post-Activity Assessment

Listen to students' answers to the concluding questions about how this lesson will help them solve the engineering design challenge. Evaluate if they understand what they are tasked with designing.

Duplication Masters

- 2.A Client Memo 1
- 2.B Activity 1: Human Control
- 2.C Activity 2: Sphero Draw
- 2.D Activity 3: Sphero Draw Challenge
- 2.E Activity 4: Sphero Block Coding
- 2.F Sphero BOLT Evaluation Sheet

2.A Client Memo 1

Dear Engineers,

Thank you for agreeing to work with us on this engineering design challenge of designing an electronic expansion pack for the Sphero BOLT. In response to what you said you would need to learn in order to solve the problem, I have provided the following lessons. I hope these activities will provide insight on how the Sphero BOLT works to help you develop items to sell on the side.

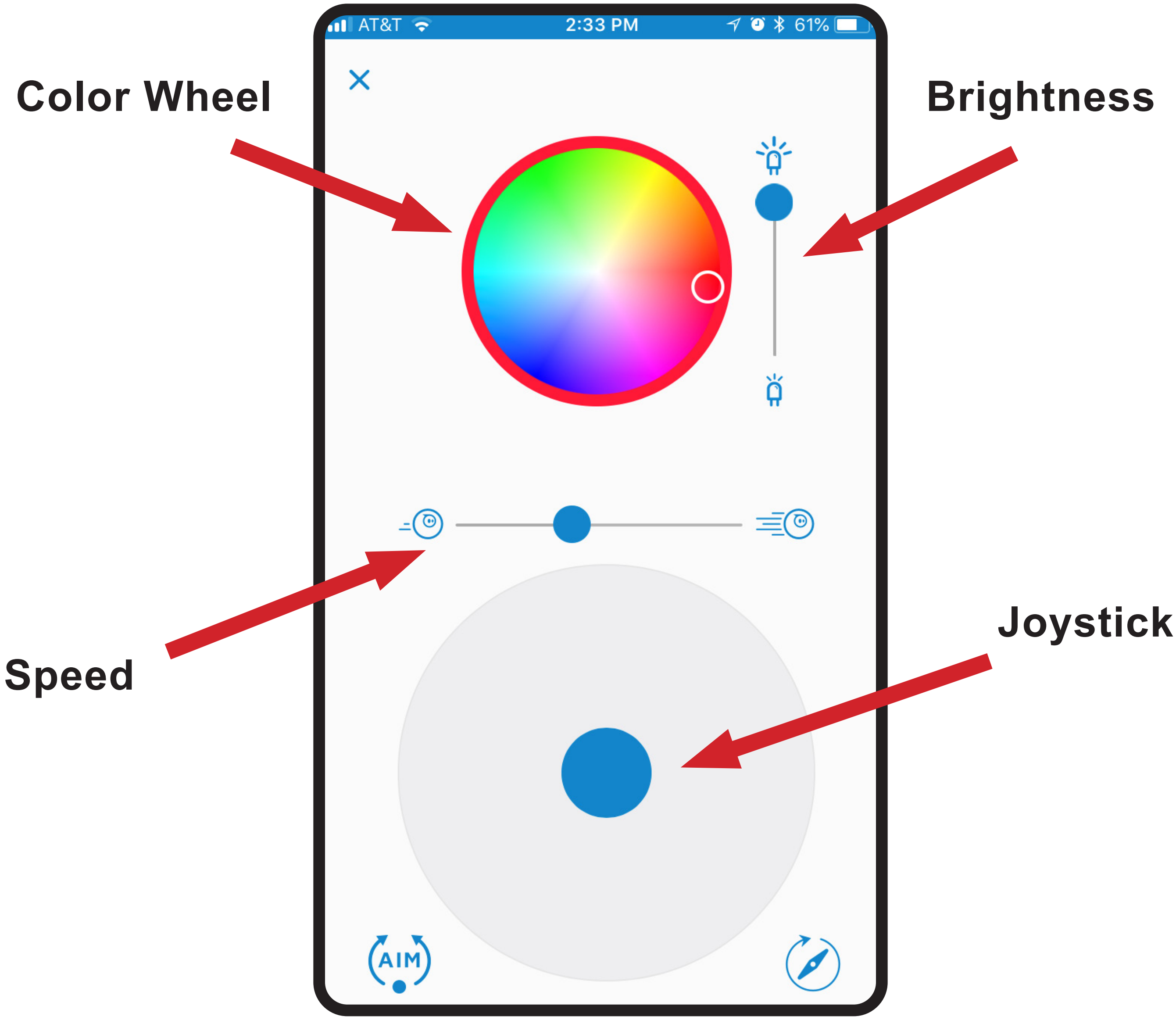
Sincerely,

Mike Rowbit

Mike Rowbit
Engineer
BLEEEP (BLossom Engineering Electronic Expansion Packs)

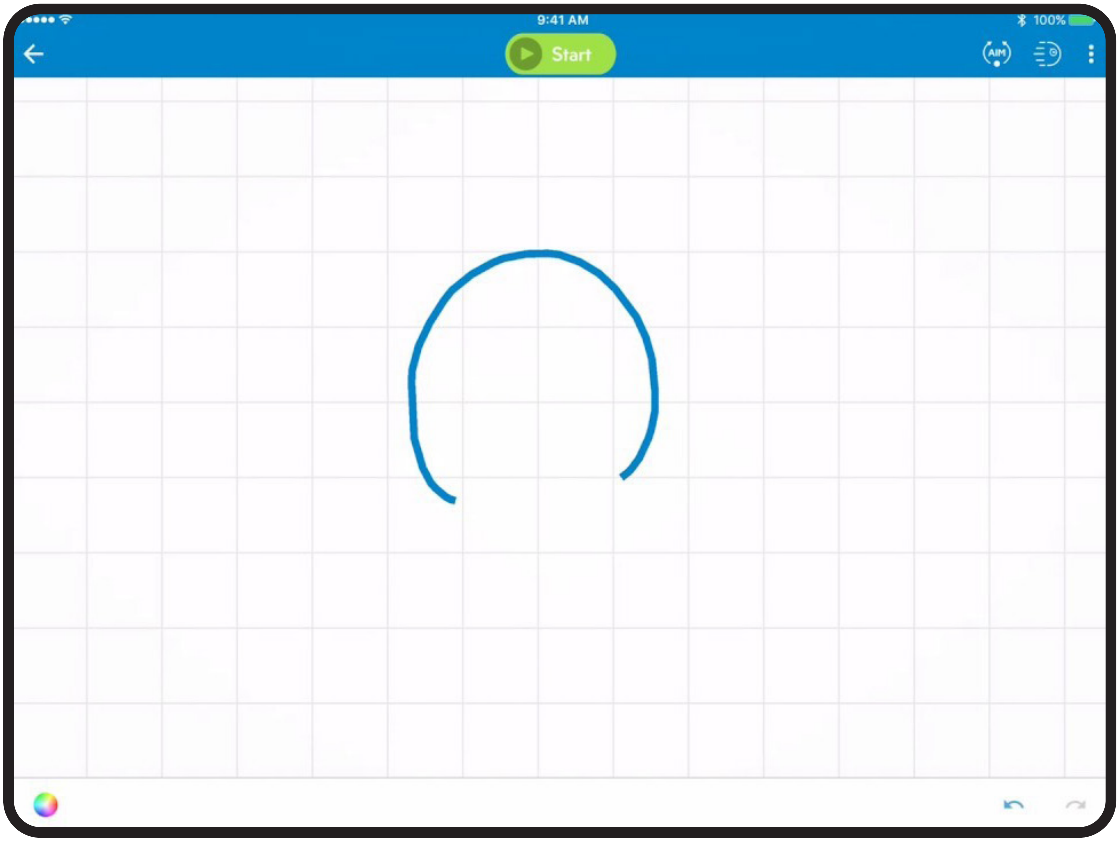
2.B Activity 1: Human Control

1. Open the Sphero Edu App.
2. Connect to the Sphero BOLT.
3. Click on Drive and use the AIM button to adjust the blue light so it is pointing toward you.
4. Use the color wheel to set the color displayed by your BOLT. Choose any color you like and feel free to change it as much as you want!
5. Adjust the brightness by using the slider next to the color wheel. You can choose any level of brightness that you like.
6. Use the Joystick button to drive your BOLT around the room.
7. Adjust the speed of your BOLT by using the slider in the middle of the screen.



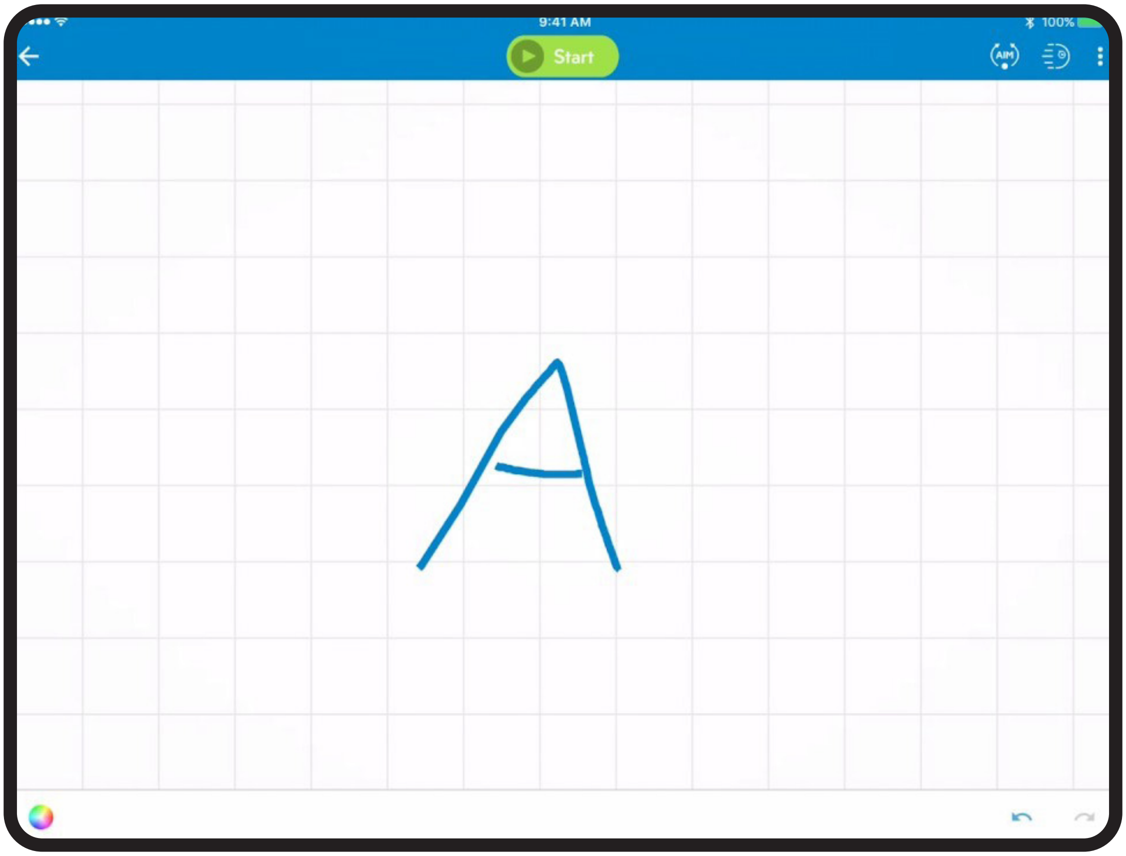
2.C Activity 2: Sphero Draw

1. Open the Programs tab, click the + button to add new and select the “Draw” program. Be sure your BOLT is also selected.
2. Place your BOLT on the floor.
3. Use the white canvas area to draw a shape, then click “Start”.
4. Draw shapes of various designs and sizes to see how your BOLT performs while running the program.
5. Once you feel comfortable with this function, move to Activity 3.



2.D Activity 3: Sphero Draw Challenge

1. Place a sheet of paper on the floor and place your BOLT on top of the sheet.
2. Place a disposable cup over the top of your BOLT.
3. Use tape to attach a marker to the side of the cup. The marker tip should come in contact with the paper so that it can write when moved.
4. Use the Draw program to sign your name on the canvas area.
5. Run the program and watch your BOLT sign your name on the paper.
6. Try making small adjustments to the AIM, speed, or marker location if necessary to produce a clearer signature.

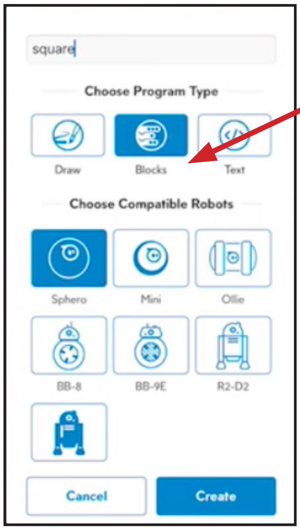


This example shows a student starting to write the name “Aris”

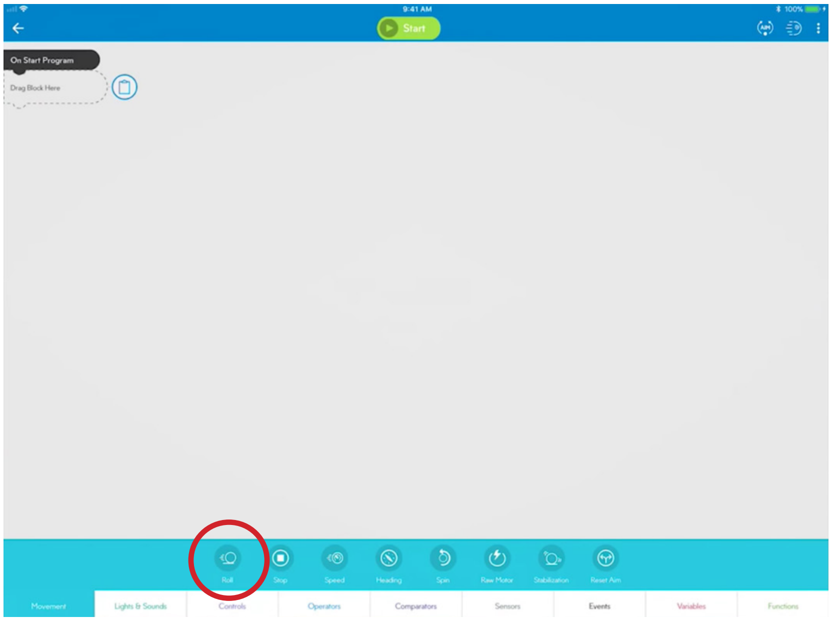
2.E Activity 4: Sphero Block Coding

1. Click the program button in the upper right to link a new program.

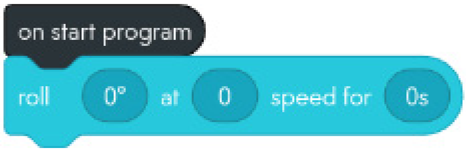
2. Name the program “Square”. Choose the “Blocks” program type.



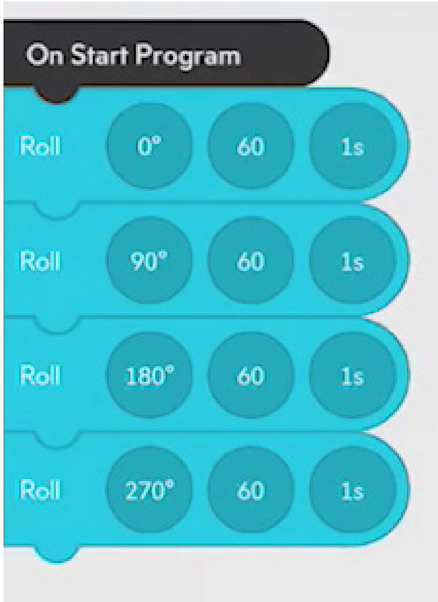
3. Stay in the Movement block. Start by adding a Roll block.



4. The Roll block will have three settings to adjust – Heading, Speed, and Duration.
    a. **Heading** is the degree that Sphero BOLT will roll at
    b. **Speed** can be set from 0 – 255
    c. **Duration** is how long the Sphero will roll for. Choose 1 second.
    d. For the first roll, use the settings shown below.

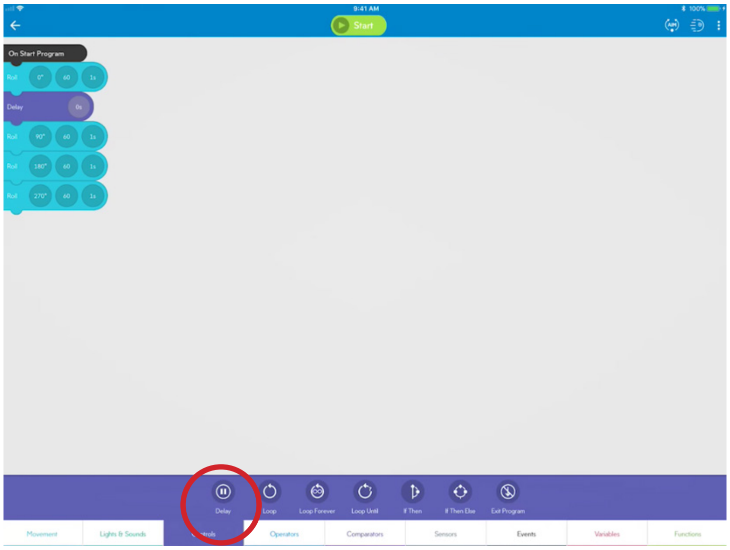


5. Tap the "roll" part of the block and then tap copy (the second icon).
6. Tap the "roll" part of the block again, and tap paste (the third icon).
7. Repeat steps 5 and 6 two more times so that you have a total of four Roll blocks. These represent the four sides of the square you will draw.
8. For blocks 2, 3, and 4, adjust until it looks like the following image:

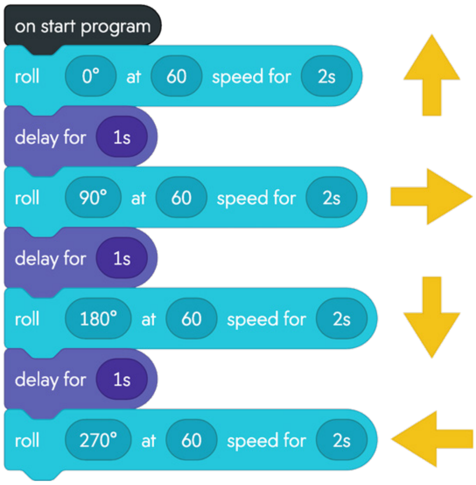


9. Place your Sphero on the ground. Tap the AIM button and drag the ring until the light on Sphero faces you.
10. Press Start to see your Sphero move in a square.
11. Tap the three dots on the top right of the screen and then "sensor data" to see the exact pattern that the Sphero completed.
12. What do you notice about the square? Was it perfect? What adjustments could be made to improve the square?
13. You may have noticed that the square has very rounded edges. This is because the Sphero never stops moving, so it does not have time to make sharp turns that better represent a square. To fix this, you can add a Delay after each Roll block.

14. At the bottom of the screen, choose Controls and then Delay. Drag your Delay block after your first Roll block.



15. Set the time for the Delay block to 1 second.
16. Copy the Delay block three times, placing one Delay block after each Roll block.



17. Run the program again. When you view the Sensor Data this time, the corners should look sharper and more like a square.

Name____ Date_______________ Period __________

2.F Sphero BOLT Evaluation Sheet

What can the Sphero BOLT do?

What questions do you have about the Sphero BOLT?

What do you wish the Sphero BOLT could do that it cannot?

LESSON THREE:

Lesson Objectives

Students will be able to:

- Name and describe in detail each of the Sphero BOLT components
- Identify the capabilities of micro:bits add-on components.

Materials

Per classroom

- EDP Poster
- BOLT Power Pack Educator Guide 2022, page 13 (BOLT components diagram)
- (8) micro:bits with battery packs and batteries
- Deconstructed cell phone
- External ultrasonic sensor
- External light sensor
- DC motor
- (2) EMF blocking fabric ~0.25 yard piece
- Cardboard ~8.5”x11”
- Flashlight
- Dark/heavy cloth
- Light colored/light cloth
- Paper cup
- Dark plastic or ceramic cup

Per student

- EDP slider w/ jumbo paperclip
- Engineering notebook

Time Required

Two 50-minute lessons

Lesson Summary

Students investigate microelectronics components (ME) that simulate current Sphero components. Students also investigate ME components, based on the cell phone, that they could use for their electronic expansion pack. Students will rotate through stations with physical devices that mimic or demonstrate the capabilities of Sphero and other potential components using a microcontroller and accessories. Some stations will display an aspect of the physical science principles behind the operation of the device via a video or graphic. Students experiment with the device to discover the constraints around operating such devices.

Background

Coding Options

Depending on students’ prior experiences in coding, more or less emphasis can be given to coding.

- **6-8 DL 3 Option 1:** The simple coding puzzle station is included. Teachers could also display the code (text or block) for the other stations that makes the device work. Students will see that a physical device and code that makes the physical device work are needed. However, students will not need to write code.
- **6-8 DL 3 Option 2:** The online simple coding station is supplemental and not included. Students utilize Microsoft Makecode (https://makecode.microbit.org) to experiment using the code template from Option 1. Students would use code blocks and a micro:bit emulator to experiment with the relationship between hardware and software. The same code blocks from Option 1 could be used and the experiments and code changes would be done online and in realtime – with results shown on the micro:bit emulator. This option could require significantly more time to implement, if unfamiliar students need first to familiarize themselves with Microsoft Makecode.
- **6-8 DL 3 Option 3:** This lesson could also be extended to teach coding of the micro:bit and sensors such that students’ prototypes are operational.

Teacher Background

Sphero Capabilities

You will need page 13 of the BOLT Power Pack Educator Guide.

Cell Phone Dissection

Here is an example video that shows the parts of a cell phone (no speaking, just a visual representation of the different components) https://youtu.be/fCS8jGc3log

Sensors

There are many different sensors and other components that can be explored. These components operate based on physical science principles.

Sensor type	How or what it senses
Bluetooth and WiFi	electromagnetic (radio) waves
Fingerprint scanner	ultrasonic waves or capacitance
Light sensor	light waves
Proximity sensor	light waves or sound waves
Accelerometer	principles of acceleration and force

For example, with distance sensors, the reflective properties of light or sound waves are used to measure the distance between the sensor and the object it is sensing. By knowing the speed of light (or sound), the sensor can calculate the distance between itself and the object based on how long it takes for the wave it sent out to return back. Some of the deep science principles will be beyond the level of middle schoolers. Where appropriate, students can understand the scientific principles behind electromagnetic, light, and sound waves. Where the physics principles are beyond students, focus solely on understanding how the device works, in general, and on the constraints of the device.
https://www.howtogeek.com/781792/there-are-a-lot-of-sensors-in-your-phone-heres-what-they-do/

Vocabulary

micro:bit	a small, programmable device that contains a microcontroller(brain) and built in sensors
sensor	an electronic device that can detect items in the physical environment such as light, sound, motion
electromagnetic wave	waves that are formed by magnetic and electric fields moving together; EM waves do not need a medium to travel
ultrasonic waves	sound waves with a frequency that human ears cannot hear; ultrasonic waves (like all sound waves) require a medium to travel

Key Terms
- micro:bit
- sensor
- electromagnetic wave
- ultrasonic
- code

Standards Addressed

Middle School
- STEL 2:S
- STEL 4:M
- STEL 4: N
- STEL 8:J
- 6-8.CD.4
- 6-8.PA.1
- MS-ETS1-1

High School
- DE 8.8

Assessments

Activity Embedded Assessment

Observe students. Ask questions about their investigations of how the components work.

Duplication Masters

3.A Component Stations

Educator Resources
- Bolt Educator Guide: https://sphero.com/pages/educator-resources
- micro:bit: https://microbit.org/
- Makecode: https://makecode.microbit.org/

•

code	a set of instructions for a computer for it to follow

Micro:bits
To set up the stations, you need to download the .hex files and place it onto the station micro:bits. Compiled code for each station is located at: https://nanohub.org/resources/39144/download/GoodIdeasRoll_HexFiles-main.zip

1. Download the file to your local machine and unzip.
2. Connect a micro:bit to your computer via the USB cord provided with the device.
   a. Your computer will register the micro:bit as a supplemental drive
3. Open the file explorer on your computer and locate the downloaded .hex files.
4. Drag one .hex file from the computer to the micro:bit drive to upload code to the micro:bit.
   a. You should see a flashing yellow light on the micro:bit, which indicates that the micro:bit is being “flashed” with the code.
5. Test the micro:bit functionality as described by the station that the code corresponds to.
6. Disconnect the micro:bit from your computer.
7. Repeat for the remaining micro:bits using the corresponding code for the station.
8. When the stations are set-up for class, you will power them with a battery pack.
9. Keep extra batteries on hand, especially for the Bluetooth and Motor stations, which can use more power than the other stations.

Github also contains uncompiled code for each station as a separate repository which you can get by going here: https://github.com/ajonespenn/

Station	Hex File	Uncompiled Code Repository
1. Accelero-meter	Accelerometer.hex	Accelerometer (Python)
2. Light Sensor	microbit-IoT_Light_SensorBit.hex	LightSensor_SensorBit (makecode)

Station	Hex File	Uncompiled Code Repository
3. Capa-cative Touch	microbit-CapacativeTouch.hex	Capacitivetouch (makecode)
4. Simple Code	microbit-SimpleCodeStation.hex	Simplecodestation (makecode)
5. Ultrasonic Proximity	microbit-DistanceSensor_SensorBit.hex	Distancesensor (makecode)
6. Bluetooth	BluetoothReciever.hex BluetoothTransmitter.hex	Bluetooth (Python)
7. Motor	microbit-WhileMotor.hex	Whilemotor (makecode)

Before the Activity

- Code the micro:bits and sensors for the stations using the supplementary instructor materials. Each configuration should be operational before the activities begin.
- Create the Posters/graphics that represent the science or general properties behind the associated stations.
- 5 Copies of the BOLT Schematic from page 13 of the BOLT Power Pack Educator Guide
- For 6-8 DL.3 Options 1 & 2 - Create the Posters/graphics that show the code for each station.
- Set up the stations at various locations in the classroom. The station will include the working device the science/properties poster and the code poster (for coding extensions).

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*

2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client.* Point out the “Problem” block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. Say: Before we can start designing solutions, we need more information. **Ask:** *What step of the engineering*

design process are we in? The students should identify that they are in the “Learn” stage.

3. **Identify what students need to learn about. Say:** *In the previous lesson, you learned about how to use a Sphero.* **Ask:** *What other information will you need to know in order to solve the problem?*

Activity

4. **Show cell phone sensor video. Say:** *Today, you will go around to different stations to experiment with some of the types of sensors and other components that are used in the Sphero and cell phones. We will watch this video about the different cell phone components to get an idea of what is available to us for our electronic expansion pack.* Show the video on the sensors of a cell phone and what they do: https://youtu.be/CxC1KCoGbIM

5. **Introduce the Component Stations. Say:** *For the rest of today, we are going to explore different components used in the Sphero or cell phones. At each station you will experiment with a simulation. The simulations use a micro:bit, which is a small computer that is programmed to tell the component what to do. This is similar to how the Sphero and smart phone have a small computer that is programmed to tell all its components what to do.* [Show the micro:bit diagram.] *The micro:bit acts as the brain that sends information to and receives information from the sensor or component. [(code option) The micro:bit must be programmed by a human using a programming language also called “code.” Each component you will explore has different capabilities and constraints that are important to know and record in your notebooks. As you investigate the components, think about how they work in the Sphero or cell phone and how you might use them in your electronic expansion pack design.*

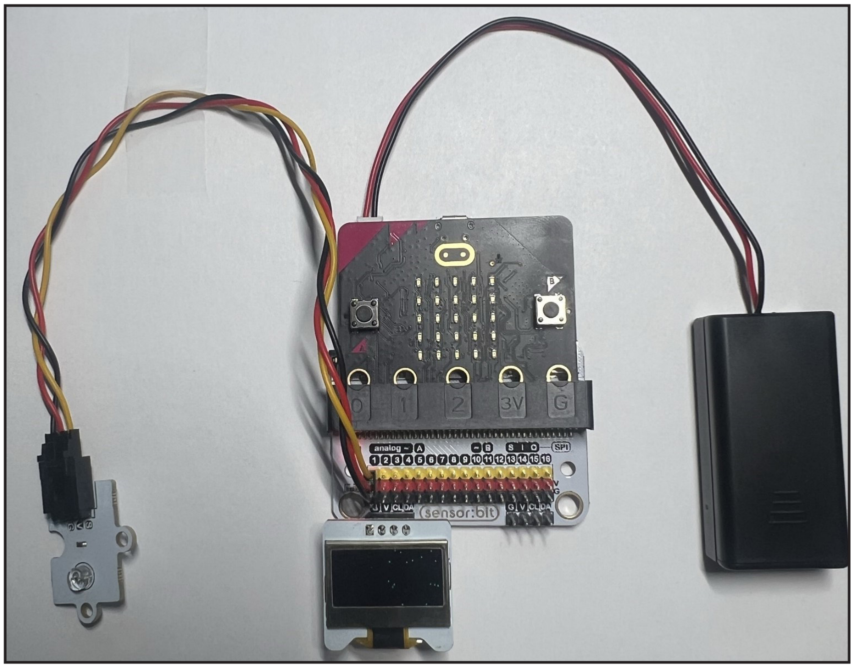
6. **Complete the Sensor Stations:** Have students rotate through the stations labeled in the classroom using the handout 3.A. There should be no more than four students at each station. Spend 10-15 minutes at each station performing the activities indicated.

Day 1 Stations

Station 1: Accelerometer sensor

Summary: Use a micro:bit programmed to show an arrow that always points in the direction the micro:bit is tilted (left, right, up down) (X and Y axis.) Have students rotate the micro:bit to confirm. Have students lift the micro:bit in the air or hold the micro:bit close to the ground (Z axis.) Does the height of the micro:bit affect its ability to sense tilt in the X/Y axis?

Station 2: Light sensor
Summary: Use a micro:bit and an attached external light sensor on Pin 1. The micro:bit is programmed to display the level of light detected by the sensor. Students can experiment with shining a bright light on the sensor, covering the sensor with a dark cloth, covering it with a cup. Students can note what light levels are detected for each situation. (extra materials: cup, dark cloth, flashlight) Students can note: light level sensitivity of the sensor.



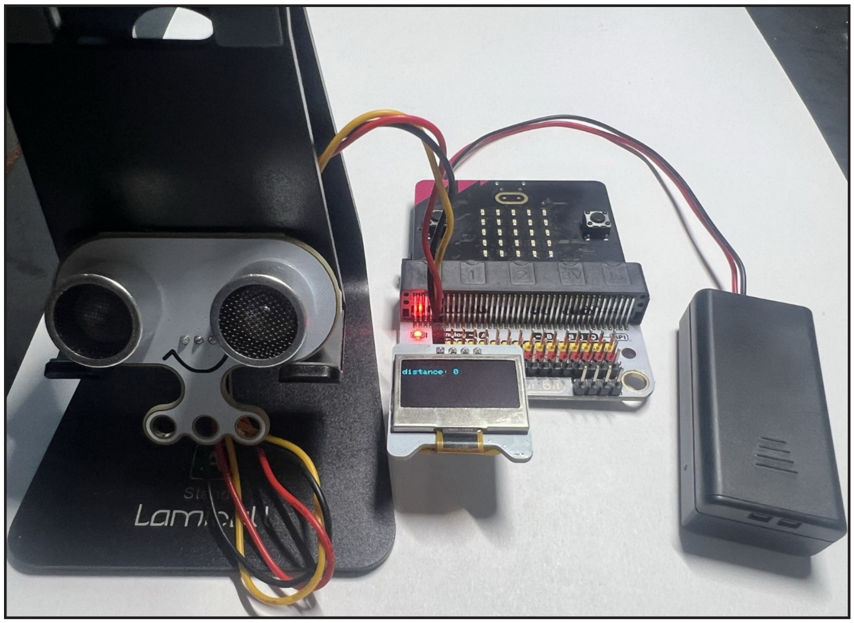
Station 3: Capacitive touch station
Summary: Students watch a video. Use the touch sensor on the micro:bit. When touched, the LED will flash a symbol and the micro:bit will make a noise. Students experiment with touching using a bare finger, a latex/nitrile glove covered finger, a fabric glove covered finger, their fingernail, etc.

Station 4: Code Station
Students complete a code puzzle using printed out blocks of code. Code option 2: Makecode, online coding (not included)

Day 2 Stations

Station 5: Ultrasonic Proximity sensors

Summary: Use a micro:bit with an attached external ultrasonic distance sensor on Pin 1. The micro:bit is programmed to sound a buzzer when something comes within its scope of distance sensing. Students can experiment with how close objects have to be before they are sensed by the distance sensor. (extra materials: ruler or tape measure, medium sized piece of cardboard to use for more easily triggering the sensor). Students can note: distance constraints for triggering the sensor.

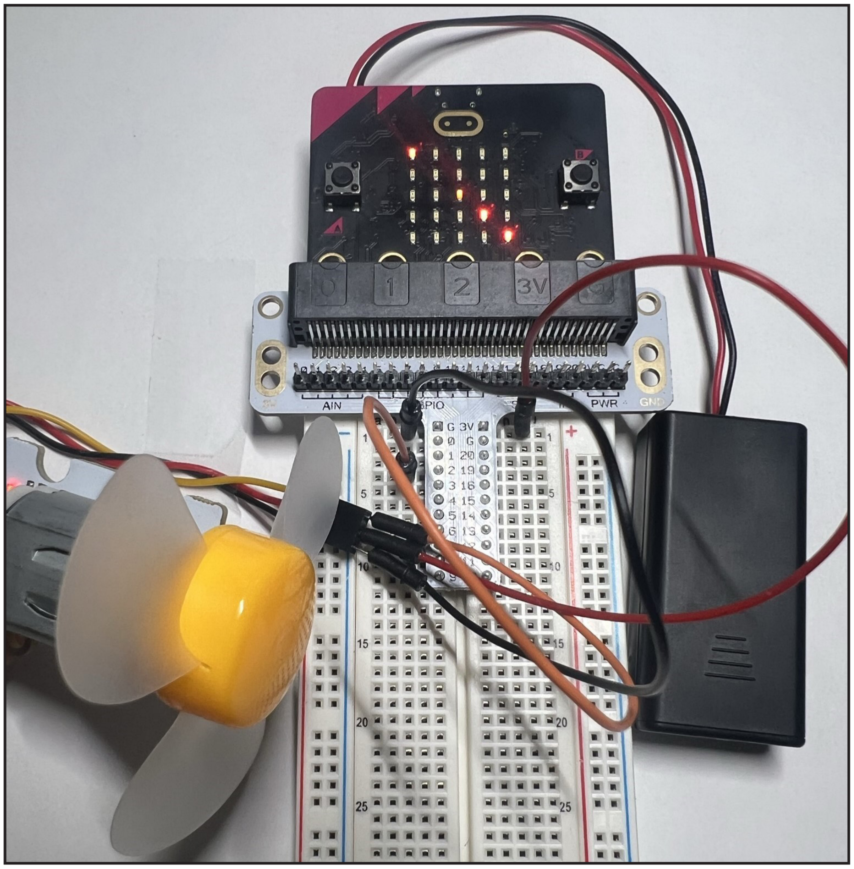


Stations 6: Bluetooth Simulation stations

Summary: Use two micro:bits programmed to communicate with each other using Bluetooth simulation via radio wave communication. This builds on the accelerometer station from Day 1. One “sender” micro:bit will perform the physical tilting but the other “receiver” micro:bit will show the arrow indicating which direction the sender is tilting. An Electromagnetic wave diagram will show different frequencies used for different things. Bluetooth operates in the 2.4 GHz band. Students experiment with distance between devices and interference. For distance, two people take devices and walk further away from each other. Students can use a piece of nickel-copper fabric (EMF blocking) to experiment with blocking signals for interference. Students can go outside of the classroom with the sender micro:bit. Students can note: Distance constraints and constraints about interference.

NOTE: For the Bluetooth Simulation Station - Although the micro:bit does have Bluetooth capabilities, we are simulating Bluetooth communication using the micro:bit radio feature. Both protocols operate at 2.4Ghz, however the radio communication is much easier to demonstrate for the lesson as it does not require a pairing phase.

Station 7: Motor/Servo Station
Summary: Use a micro:bit attached to an external DC motor on Pin 2. The micro:bit is programmed to turn the motor on while the A button is pressed and off when the A button is released.



Note: Different DC motors hook up differently. This setup uses the ELECFREAKS Octopus Motor Brick (https://shop.elecfreaks.com/products/elecfreaks-octopus-motor-brick?_pos=2&_sid=598d6ecc4&_ss=r). Other motors may require different wiring to function properly.

Closure

7. **Connect this activity to the Engineering Design Challenge (each day).** Ask students to discuss in their teams and report

out:

- How do the physical properties of electromagnetic or sound waves help some sensors to work?
- What are some of the constraints of the simulated devices you've experimented with today?
- How will your knowledge of the components you saw today contribute to your design?

3.A Station 1: Accelerometer Sensor

Learning Goal:

Explain what the accelerometer sensor senses and one way that it is used. (code option) Explain one relationship between the code and the operation of the sensor.

Instructions:

1. Watch the short video that gives examples of uses and briefly explains the science. https://www.youtube.com/watch?v=RLQGZI0IpjQ

2. Have your team experiment with the built-in accelerometer function of the micro:bit in the following ways.

   Action: Rotate the micro:bit in several directions
   Observe: What happens on the micro:bit screen as you rotate the device?

   Action: Try raising the micro:bit high in the air or placing it low to the ground and rotating it.
   Observe: Does raising or lowering the micro:bit change anything about how it operates?

   Action: Look briefly at the code that makes this station work.

3. Discuss the following questions.

   What do you think the command "display.show()" does?

4. Answer these questions in your notebooks.

   Q1: How does the accelerometer help a cell phone or car to function better?
   Q2: How might you use this sensor in your design?
   Q3: What constraints do you need to consider if you use this sensor?

3.B Station 2: Light Sensor

Learning goal:

Explain that the ambient light level of the environment can be detected by a sensor.

The light must be within the visible spectrum range of 38 nm to 700 nm. The sensor reading on the micro:bit is a relative, sensor specific reading that indicates the light level being sensed.

Instructions:

1. Watch the short video about light sensors: https://youtube.com/clip/UgkxvAtIXH6qQazY0UKP4sfCa0k6JnBghG-A
2. The LED screen shows the amount of light that the sensor is receiving. This measurement is in lux units. Have your team experiment with the external light sensor attached to the micro:bit.
3. You will experiment with placing different objects over the sensor to see how they affect the light readings.

   Action: Place your hand over the light sensor
   Observe: What reading does the sensor give?

   Action: Place different cups over the light sensor
   Observe: For each cup, how do readings from the sensor change?

   Action: Place different pieces of fabric over the light sensor.
   Observe: For each type of fabric, what reading does the sensor give?

   Action: Shine the flashlight on the sensor
   Observe: What is the maximum reading you can get?
4. Discuss the following questions.

   What did you notice about the light sensor readings for each type of object?
   Do you think this code looks complicated or simple? Why?
5. Answer these questions in your notebooks

   Q1: How does being able to sense the level of light in the atmosphere help your cell phone to function better?
   Q2: How might you use this sensor in your design?
   Q3: What constraints do you need to consider if you use this sensor?

3.C Station 3: Capacitive Touch Sensor

Instructions

The human body is a conductor of electricity. Examine how that can be used in sensors.

1. Watch the short video about capacitive touch https://www.youtube.com/watch?v=IdWXT391FJE
2. Experiment with what will register on the sensor.

   Action: Touch the micro:bit logo with your finger.
   Observe: How long do you have to touch it before the buzzer sounds?

   Action: Now experiment with touching the logo in various ways to see if the buzzer still sounds.
   - Put on the rubber gloves
   - Put on fabric gloves
   - Touch with your fingernail
   - Use a pencil or pen to touch it.
3. Discuss: What experiments made the buzzer sound and which didn't.
4. Answer these questions in your notebooks

   Q1: Why do you think that some of ways you tried did not make the buzzer sound?
   Q2: How might you use this sensor in your design?
   Q3: What constraints do you need to consider if you use this sensor?

Instructions

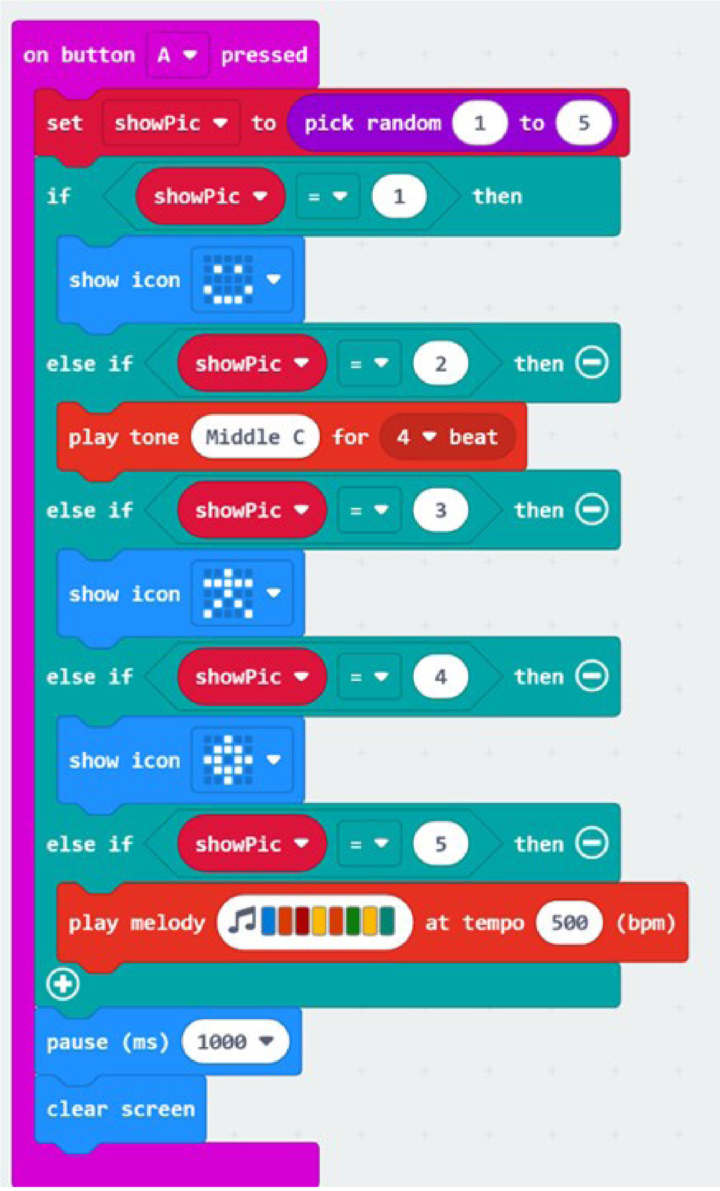
Microelectronic devices require coding to make them work. Understand the logic in a computer code
.

1. Look at the full code page. This type of code is called Block Coding because the code fragments are contained in visible, colorful blocks that can be assembled together to make a program.
2. This code corresponds to the micro:bit at this station. The micro:bit operates like this:
   a. When you press the 'A' button, it chooses a random number between 1 and 3
   b. Based on the number is chooses, the micro:bit will do 1 of three things.
      i. For #1, the micro:bit will show a smiley face.
      ii. For #2, the micro:bit will play a short musical clip.
      iii. For #3 the micro:bit will show a stick figure.
3. Look at the block code and see if you can correspond the code to the way the micro:bit functions. You will see a few "if" statements, and code that tell the micro:bit what to do for each number between 1 and 3.
4. Now, using the code puzzle, duplicate the code that is show on the Full code page. Once all team members agree that the code is correct, move to step 5.
5. Now think about if we wanted to change what the micro:bit shows for each number:
   a. For #1, the micro:bit will show a stick figure.
   b. For #2, the micro:bit will show a smiley face.
   c. For #3 the micro:bit will play a short musical clip.
6. Work with your team mates to change the location of the puzzle pieces so that the code corresponds to the new scenario in step 5.
7. Answer these questions in your notebooks.

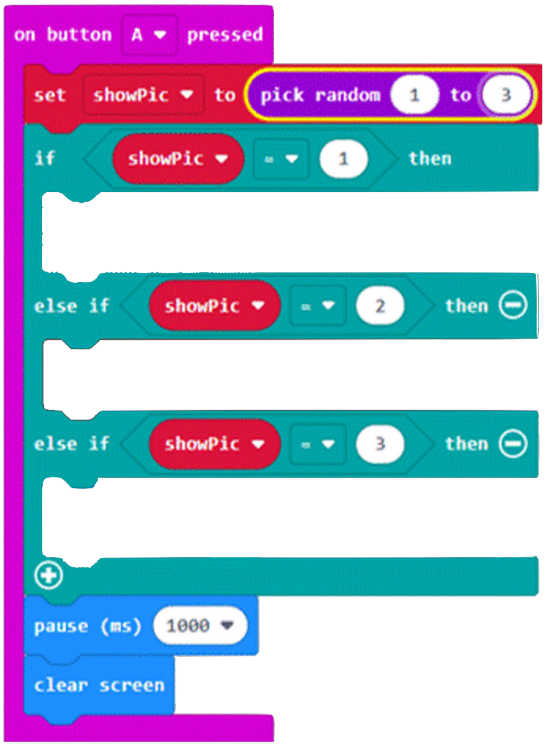
   Q1: How did you change the code puzzle for step # 5 and 6? Draw the new order of the code blocks in your notebook.

3.D Station 4: Code Puzzle Station

Full Code Block



Code Puzzle Block



Puzzle Code Block - Code Explanation

1. Randomly pick a number between 1 and 3, and save the value in a variable called 'showPic'.
2. If the number is 1, then ___________.
3. If the number is 2, then ___________.
4. If the number is 3, then ___________.
5. Wait for 1000 milliseconds.
6. Clear the screen.

3.E Station 5: Ultrasonic Proximity Sensor

Instructions

Explain how sound wave properties play a part in sensing distance.

1. Complete the reading and look at the figure below as you view the video: https://www.youtube.com/embed/sYLMW7QhAJQ?start=1&end=79
2. You will determine how close you need to be to the sensor to set off the alarm.
   - Action: Use the piece of cardboard to experiment with the sensing range of the distance sensor. Hold the cardboard at the level of the sensor, directly in front of it, starting from 5 feet way. Slowly move the cardboard toward the sensor until you hear the alarm.
     Observe: Measure how close you need to be to the sensor before it reacts.
   - Action: Using the cardboard, try different angles of approach. For example, instead of coming directly in front of the sensor, come in from the left side of the sensor or the right, top or bottom sides.
     Observe: How does the angle of approach affect whether or not the sensor reacts?
   - Notebook: How do sound waves help the sensor to work?
   - Notebook: How might you use this sensor in your design?
   - Notebook: What constraints do you need to consider if you use this sensor?

3.A Component Stations

Station 1: Accelerometer sensor
Learning Goal: Explain what the accelerometer sensor senses and one way that it is used. (code option) Explain one relationship between the code and the operation of the sensor.

Instructions:
1. Watch the short video that gives examples of uses and briefly explains the science. https://www.youtube.com/watch?v=RLQGZI0IpjQ
2. Have the team experiment with the built-in accelerometer function of the micro:bit in the following ways and answer the questions in their notebooks:
   - Action: Rotate the micro:bit in several directions
     Observe: What happens on the micro:bit screen as you rotate the device?
   - Action: Try raising the micro:bit high in the air or placing it low to the ground and rotating it.
     Observe: Does raising or lowering the micro:bit change anything about how it operates?
   - Action: Look briefly at the code that makes this station work.
     Discuss: What do you think the command “display.show()” does?
   - Notebook: How does the accelerometer help a cell phone or car to function better?
   - Notebook: How might you use this sensor in your design?
   - Notebook: What constraints do you need to consider if you use this sensor?

Station 2: Light sensor
Learning goal: Explain that the ambient light level of the environment can be detected by a sensor.

The light must be within the visible spectrum range of 38 nm to 700 nm. The sensor reading on the micro:bit is a relative, sensor specific reading that indicates the light level being sensed.

Instructions:
1. Watch the short video about light sensors: https://youtube.com/clip/UgkxvAtIXH6qQazY0UKP4sfCa0k6JnBghG-A
2. The LED screen shows the amount of light that the sensor is receiving. This measurement is in lux units. Have your team experiment with the external light sensor attached to the micro:bit.
3. You will experiment with placing different objects over the sensor to see how they affect the light readings.
   - Action: Place your hand over the light sensor
     Observe: What reading does the sensor give?
   - Action: Place different cups over the light sensor
     Observe: For each cup, how do readings from the sensor change?
   - Action: Place different pieces of fabric over the light sensor.
     Observe: For each type of fabric, what reading does the sensor give?
   - Action: Shine the flashlight on the sensor
     Observe: What is the maximum reading you can get?
   - Discuss: What did you notice about the light sensor readings for each type of object?

- Discuss: Do you think this code looks complicated or simple? Why?
- Notebook: How does being able to sense the level of light in the atmosphere help your cell phone to

function better?
- Notebook: How might you use this sensor in your design?
- Notebook: What constraints do you need to consider if you use this sensor?

Station 5: Ultrasonic Proximity sensor
Learning Goal: Explain how sound wave properties play a part in sensing distance.

Instructions:
1. Complete the reading and look at the figure below as you view the video: https://www.youtube.com/embed/sYLMW7QhAJQ?start=1&end=79
2. You will determine how close you need to be to the sensor to set off the alarm.
    - Action: Use the piece of cardboard to experiment with the sensing range of the distance sensor. Hold the cardboard at the level of the sensor, directly in front of it, starting from 5 feet way. Slowly move the cardboard toward the sensor until you hear the alarm.
      Observe: Measure how close you need to be to the sensor before it reacts.
    - Action: Using the cardboard, try different angles of approach. For example, instead of coming directly in front of the sensor, come in from the left side of the sensor or the right, top or bottom sides.
      Observe: How does the angle of approach affect whether or not the sensor reacts?
    - Notebook: How do sound waves help the sensor to work?
    - Notebook: How might you use this sensor in your design?
    - Notebook: What constraints do you need to consider if you use this sensor?

3.A Component Stations

Station 1: Accelerometer sensor
Learning Goal: Explain what the accelerometer sensor senses and one way that it is used. (code option) Explain one relationship between the code and the operation of the sensor.

Instructions:
1. Watch the short video that gives examples of uses and briefly explains the science. https://www.youtube.com/watch?v=RLQGZI0IpjQ
2. Have the team experiment with the built-in accelerometer function of the micro:bit in the following ways and answer the questions in their notebooks:
   - Action: Rotate the micro:bit in several directions
     Observe: What happens on the micro:bit screen as you rotate the device?
   - Action: Try raising the micro:bit high in the air or placing it low to the ground and rotating it.
     Observe: Does raising or lowering the micro:bit change anything about how it operates?
   - Action: Look briefly at the code that makes this station work.
     Discuss: What do you think the command “display.show()” does?
   - Notebook: How does the accelerometer help a cell phone or car to function better?
   - Notebook: How might you use this sensor in your design?
   - Notebook: What constraints do you need to consider if you use this sensor?

Station 2: Light sensor
Learning goal: Explain that the ambient light level of the environment can be detected by a sensor.

The light must be within the visible spectrum range of 38 nm to 700 nm. The sensor reading on the micro:bit is a relative, sensor specific reading that indicates the light level being sensed.

Instructions:
1. Watch the short video about light sensors: https://youtube.com/clip/UgkxvAtIXH6qQazY0UKP4sfCa0k6JnBghG-A
2. The LED screen shows the amount of light that the sensor is receiving. This measurement is in lux units. Have your team experiment with the external light sensor attached to the micro:bit.
3. You will experiment with placing different objects over the sensor to see how they affect the light readings.
   - Action: Place your hand over the light sensor
     Observe: What reading does the sensor give?
   - Action: Place different cups over the light sensor
     Observe: For each cup, how do readings from the sensor change?
   - Action: Place different pieces of fabric over the light sensor.
     Observe: For each type of fabric, what reading does the sensor give?
   - Action: Shine the flashlight on the sensor
     Observe: What is the maximum reading you can get?
   - Discuss: What did you notice about the light sensor readings for each type of object?

- Discuss: Do you think this code looks complicated or simple? Why?
- Notebook: How does being able to sense the level of light in the atmosphere help your cell phone to

function better?
- Notebook: How might you use this sensor in your design?
- Notebook: What constraints do you need to consider if you use this sensor?

Station 3: Capacitive Touch Station
Learning goal: The human body is a conductor of electricity.

Instructions:
1. Watch the short video about capacitive touch https://www.youtube.com/watch?v=IdWXT391FJE
2. Experiment with what will register on the sensor.
   - Action: Touch the micro:bit logo with your finger.
     Observe: How long do you have to touch it before the buzzer sounds?
   - Action: Now experiment with touching the logo in various ways to see if the buzzer still sounds.
     Put on the rubber gloves
     Put on fabric gloves
     Touch with your fingernail
     Use a pencil or pen to touch it.
     Discuss: What experiments made the buzzer sound and which didn't.
   - Notebook: Why do you think that some of ways you tried did not make the buzzer sound?
   - Notebook: How might you use this sensor in your design?
   - Notebook: What constraints do you need to consider if you use this sensor?

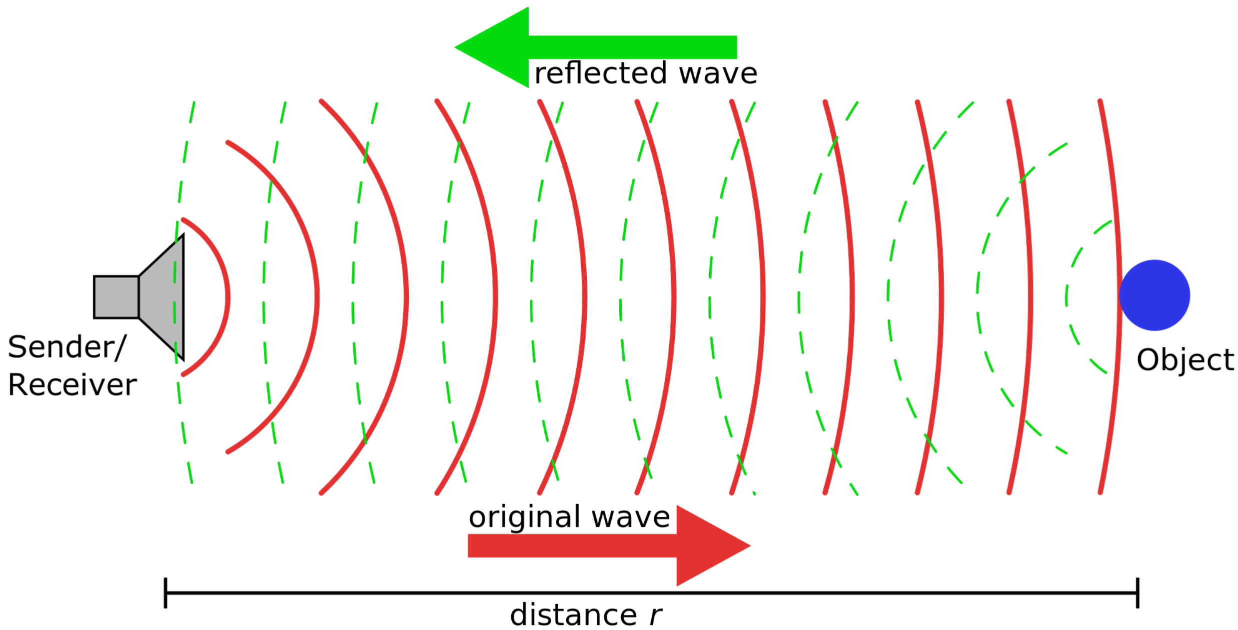
Station 4: Code Station, option 1: Simple code puzzle station
Learning goal: Microelectronic devices require coding to make them work.

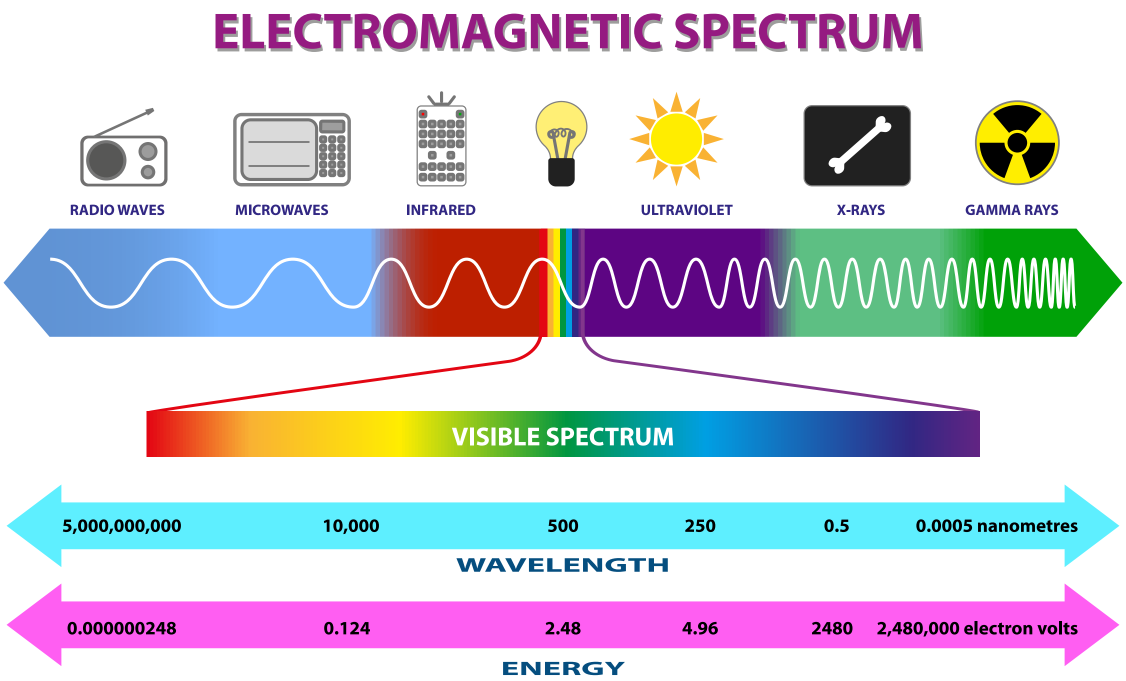
Instructions:
1. Look at the Full code page. This type of code is called Block Coding because the code fragments are contained in visible, colorful blocks that can be assembled together to make a program.
2. This code corresponds to the micro:bit at this station. The micro:bit operates like this:
   a. When you press the 'A' button, it chooses a random number between 1 and 3
   b. Based on the number is chooses, the micro:bit will do 1 of three things.
      i. For #1, the micro:bit will show a smiley face
      ii. For #2 the micro:bit will play a short musical clip
      iii. For #3 the micro:bit will show a stick figure.
3. Look at the block code and see if you can correspond the code to the way the micro:bit functions. You will see a few "if" statements, and code that tell the micro:bit what to do for each number between 1 and 3.
4. Now, using the code puzzle, duplicate the code that is show on the Full code page.
5. Discuss: Once all team members agree that the code is correct, move to step 5.
6. Now think about if we wanted to change what the micro:bit shows for each number:
   a. For #1, the micro:bit will show a stick figure.
   b. For #2, the micro:bit will show a smiley face.

Station 6: Bluetooth Simulation station
Learning goal: Explain how electromagnetic waves allow for communication between devices.

Instructions:

1. Watch the video for an overview of how Bluetooth works: https://www.youtube.com/embed/1I1vxu5qIUM?start=1&end=221
2. At this station, two micro:bits are set up to speak to each other. This station is somewhat like the Accelerometer station from last time. But, instead of the arrow on the micro:bit pointing in the direction you tilt it, a different micro:bit will control the direction the arrow points in. One micro:bit will act as a sender (like the cell phone in the video.) The other micro:bit is the receiver (like the earbuds in the video.) You will rotate the sender like you did at the Accelerometer station. However, the sender micro:bit will not display anything. The receiver micro:bit will display the direction that the sender micro:bit is rotated in. The two micro:bits are communicating with each other using electromagnetic waves, like Bluetooth.
    - Action: Rotate the sender micro:bit and observer the receiver micro:bit.
      Discuss: What do you notice about the relationship between the sender and receiver?
    - Action: Try moving the receiver far away from the sender, but remain in the same room.
      Discuss: How far away can the sender and receiver be and still communicate?
    - Action: Try moving the receiver beyond the same room so that there is a wall between it and the sender.
      Discuss: Can the sender and receive still communicate? How can you tell?
    - Action: Try covering the sender micro:bit with the electromagnetic signal blocking case.
      Discuss: Does this experiment block the signal? How can you tell?
    - Notebook: In what ways can you disrupt the electromagnetic wave signals between the two micro:bits?
    - Notebook: How might communication between two different or distant components be useful in your design?
    - Notebook: What constraints do you need to consider if you use Bluetooth communication?


reflected wave
Sender/
Receiver
Object
original wave
distance r


ELECTROMAGNETIC SPECTRUM
RADIO WAVES
MICROWAVES
INFRARED
ULTRAVIOLET
X-RAYS
GAMMA RAYS
VISIBLE SPECTRUM
5,000,000,000
10,000
500
250
0.5
0.0005 nanometres
WAVELENGTH
0.000000248
0.124
2.48
4.96
2480
2,480,000 electron volts
ENERGY

Station 7: Motor Station
Learning goal: Gain a deeper understanding of how DC motors work.

Instructions:
1. (optional)Watch a video on how DC motors work: https://www.youtube.com/watch?v=1AaUK6pT_cE
2. This station uses a micro:bit connected to a DC motor with a fan on the shaft.
    - Action: Pressing the A button on the micro:bit turns on the DC motor. Releasing the A button turns off the DC motor.
      Discuss: Why does the motor start spinning when the A button is pressed?
    - Action: Use the strong magnet at this station. Place the magnet near or on the DC motor. Press the A button.
      Discuss: Do you notice any significant degradation of the motor's operation? What effect might a strong magnet have on the DC motor and why?
    - Notebook: The Sphero has a motor in it. How does the presence of an internal motor affect your possible electronic expansion pack design?

LESSON FOUR:

Lesson Objectives

Students will be able to:

- Use Ohms Law to calculate voltage, current, and resistance
- Read a schematic and assemble electronic circuits.

Materials

Per classroom

- EDP Poster

Per group

- breadboard
- resistors
- LEDs
- transistors
- capacitors

Per student

- EDP slider w/ jumbo paperclip
- Laptop or equivalent device
- Engineering notebook

Time Required

Two 50-minute sessions

Standards Addressed

Middle School

- Core Standard 10
- ETE – 10.1
- ETE – 10.2
- ETE – 10.3
- ETE – 10.4
- MS-PS1-3
- MS-PS2-3

High School

- STEL 2:T
- STEL 4:P
- HS-ICP3-5

Lesson Summary

The client provides a power constraint for the electronic expansion pack design. Students will investigate Ohms law to test their design for adherence to the constraint. Students will read basic circuit schematics and relate them to actual components. Students will build simple circuits.

Background

Teacher Background

Topic 1: Ohms Law

- https://youtu.be/8jB6hDUqN0Y?si=vF_GAgHoI2HegUhw

Topic 2: Simple Circuit schematics and components

- https://learn.sparkfun.com/tutorials/how-to-read-a-schematic/all
- https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_all.html

Topic 3: Basics of Electricity

- https://fliphtml5.com/lfog/hoei/basic

Vocabulary: Conductor, diode, resistor, volt, resistance, frequency, ohm, power source, LED

Before the Activity

Create packets for each team that contain the components they will use for this activity.
Component List:
breadboard, resistors (10ohms, 100ohms, 220 ohms, 6.6K ohms), capacitors (10 μF, 2100 μF) battery, battery snap, 2 LEDs, transistor (Q1 2N904 [NPN]), pushbutton, 555 IC Timer, speaker (8 ohms), photocell, jump wires, multimeter

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Say:** *Before we can start designing solutions, we need more information. Ask: What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.

3. **Identify what students need to learn about. Say:** *In the previous lesson, you learned about the different microelectronic components and sensors that can be used in your design.* Now the client has added a power constraint. **Ask:** *What other information will you need to know in order to solve the problem?*

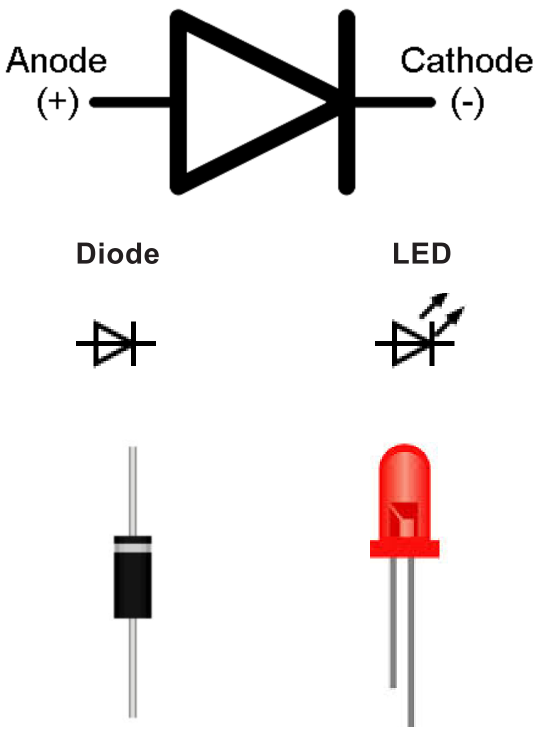
Activites

In these activities you will read schematic diagrams and translate each schematic into a physical circuit. 4F contains a diagram of electronic circuit symbols that are used in schematics.

Activity 1
LED & Resistor

A diode is a semiconductor device that has two terminals, one positive and one negative. Electricity can only flow in one direction, from the positive (anode) to the negative (cathode). LED stands for Light Emitting Diode. An LED is a diode that lights up when voltage is applied.

Figure 1: Diodes



Resistors limit the flow of electrons through a circuit. They are often used in a circuit to limit the amount of current that flows through other components. Resistance is measured in Ohms (Ω).

Key Terms

- ohms Law
- voltage
- current
- resistance
- conductor
- diode
- microcontroller
- LED

Assessments

Activity Embedded Assessment
Students produce working circuits, correctly translating the diagram into a physical circuit.

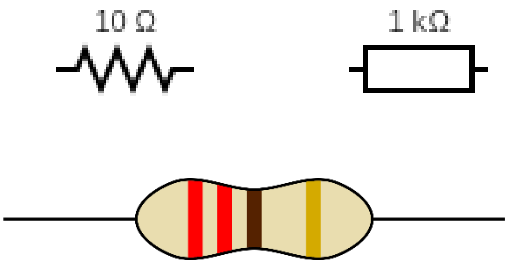
Post-Activity Assessment:
Students produce working circuits, correctly translating the diagram into a physical circuit.

Duplication Masters

4.A Client Memo
4.B Simple Circuit
4.C Simple Circuit Breadboard
4.D Simple Circuit 2 – Multimeter
4.E Pushbutton Switch Circuit
4.F Transistor Circuit
4.G Ohm's Law Triangle
4.H Electronic Circuit Symbols

Resistors

Figure 2: Resistors



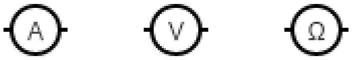
View the Simple Circuit 1 diagram. Notice the schematic symbols for the LED, resistor and battery. Now, view the picture of the physical circuit and see the correspondence between the schematic and the actual circuit.

1. Using the materials in your components kit, create the Simple Circuit 1.
2. Now, create the same circuit using a breadboard. View the picture of the circuit on the solderless breadboard and duplicate it using your components.
3. On your breadboard, take note of the resistor value, 10Ω. Change the resistor to one with a higher resistance, 1kΩ. What do you notice about the brightness of the LED?

Activity 2

Use Ohms Law and a multimeter.

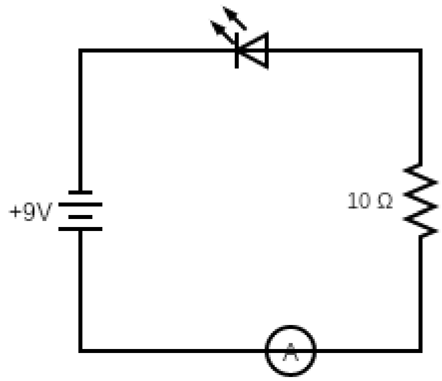
A multimeter can measure current (ammeter), voltage (voltmeter), and resistance (ohmmeter) depending on how you configure it.



In this activity, you will use a multimeter's ammeter function to measure the circuit's current from Activity 1. We will use Ohm's law to calculate the relationships between current, voltage and resistance. View the Simple Circuit 2 diagram. It is the same as the Simple Circuit 1, except now an ammeter (multimeter set to measure amps) has been inserted between the resistor and the wire leading to the positive side of the 9V battery (red wire). View the schematic for this circuit and the picture of the meter connection.

1. View the video about Ohm's law: https://youtu.be/8jB6hDUqN0Y?si=vF_GAgHoI2HegUhw
2. Using your multimeter, make sure the meter is turned off. Set the dial position to 20mA. The meter will now act as an ammeter and measure the current flowing in your circuit.
3. Insert the black meter lead into the COM socket and the red meter lead into the VΩmA socket. Turn the meter on.
4. Disconnect the black jumper wire from the breadboard so that you can insert the meter probes. Touch the black meter probe to the resistor and the red meter probe to the wire coming from the battery. Note the measurement. This is the amount of current flowing between the resistor and the battery.
5. Now, measure the current flowing between the battery and the LED. Look at the schematic in figure 1 below. It shows the ammeter positioned between the LED and the battery. Configure your multimeter leads to take the measurement and make a note of the value.

Figure 3: Simple Circuit with Ammeter



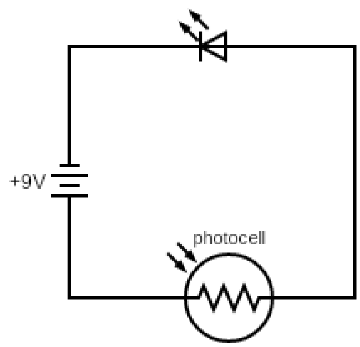
6. What do you notice about the two current measurements you took?
7. Review Ohms Law using the Ohm's Law Triangle on 4E. You know the voltage and the resistance. Calculate the expected current. Does your calculation match your multimeter measurement? If not, how do you explain the difference?
8. Change resistor to one with a higher resistance. Use Ohm's law to calculate what the current will be, then measure the current using your multimeter. Does your calculation match the multimeter measurement? If not, how do you explain the difference?

Activity 3
Build basic circuits from Schematic Diagrams
Knowing how to
In this activity, you will build basic circuits based on a schematic. The schematic contains symbols that represent the physical device. View the different symbols that can be used in a schematic on 4F. You can also investigate the symbols by going here:
https://learn.sparkfun.com/tutorials/how-to-read-a-schematic/
https://learn.sparkfun.com/tutorials/how-to-read-a-schematic/all#schematic-symbols-part-1
https://learn.sparkfun.com/tutorials/how-to-read-a-schematic/all#schematic-symbols-part-2

A. Photocell Circuit
A photocell is a special type of resistor that can sense light. The resistance changes based on the amount of ambient light that reaches the photocell. The resistance value is inversely proportional to the amount of light received. The brighter the light, the lower the resistance. In absolute darkness, the photocell will be in the megaohm's range (1.0MΩ). Shining a bright light on the photocell will drop the resistance to near zero (~8-20Ω). Experiment with the amount of light that reaches the photocell. How could you measure the amount of resistance that the photocell provides?

Figure 4: Photocell


Figure 5: Photocell Circuit



B. Capacitor Circuit
A capacitor (cap) can store electrical energy. Capacitance indicates the amount of energy a cap can store. You can charge the capacitor by connecting it to the battery. While the battery is connected, observe that the LED is lit. After at least 10 seconds, disconnect the battery. How long does the LED stay lit while not connected? Where is the energy coming from to light the LED when the battery is disconnected?

Figure 6: Capacitors

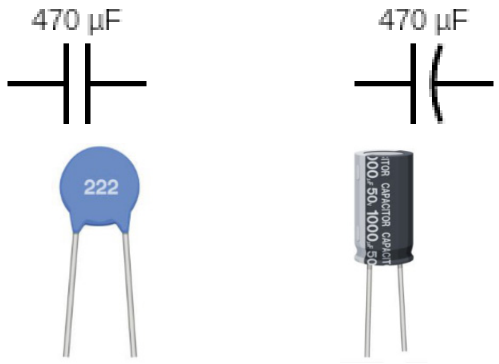
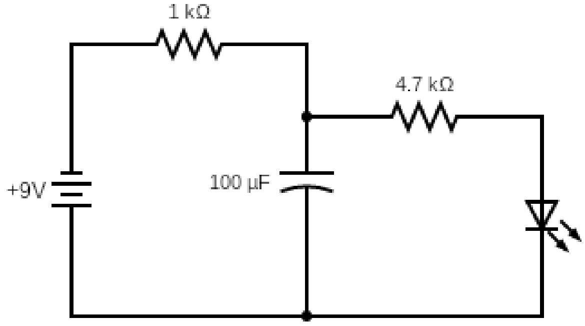


Figure 7: Capacitor Circuit

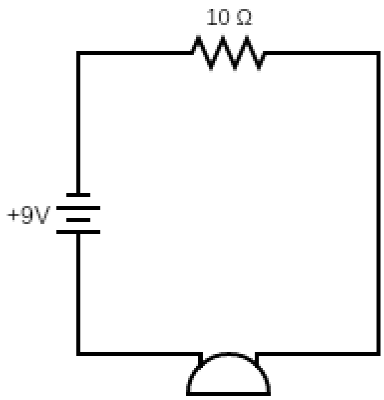


You can learn more about capacitors here:
https://learn.sparkfun.com/tutorials/capacitors/all

C. Buzzer Circuit
   This circuit is very similar to your first Simple Circuit 1 except that the LED has been replaced by a buzzer. Configure this circuit and notice if the buzzer sounds. Do you think that replacing the 10Ω resistor with a 1kΩ resistor will have any effect on the buzzer sound? Test out your hypothesis by replacing the 10Ω resistor with a 1kΩ resistor.

Figure 8: Buzzer

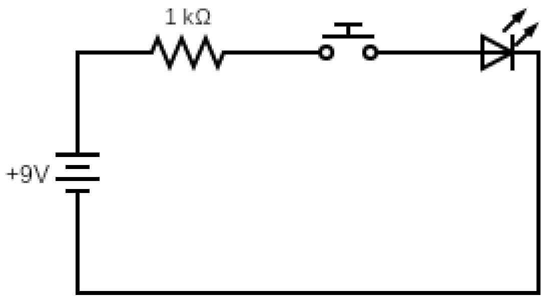
Figure 9: Buzzer Circuit



D. Push Button Switch Circuit
   The push button is a type of switch. It either allows electricity to flow through the circuit when closed, or blocks electricity from flowing when open. Building off of the Simple Circuit 1 configuration, place a pushbutton between the resistor and the LED. See 4E Diagram. When does the LED light up? Why?

Figure 10: Pushbutton Switch

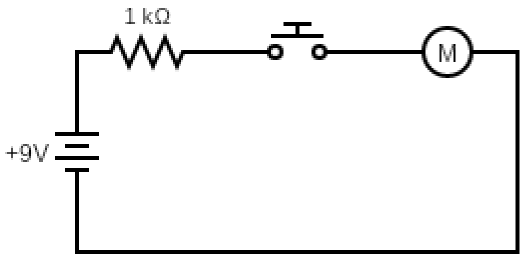
Figure 11: Push Button Switch Circuit



E. DC Motor Circuit
   You learned about DC motors in Lesson 3. The motor in that lesson was controlled by a micro:bit. In this lesson you will create a similar circuit, using a pushbutton to turn the motor on. The motor schematic below is very similar to the pushbutton circuit with the LED that you completed in an earlier activity. You will replace the LED with a DC motor.

Figure 12: DC Motor

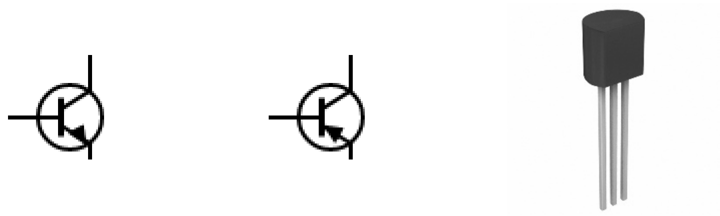
Figure 13: DC Motor Circuit



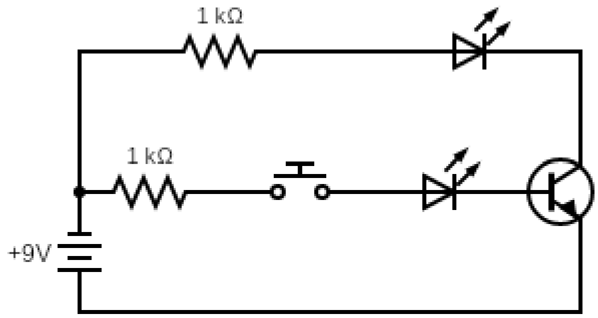
F. Transistor Circuit
   This is the most complex of all the circuits you've seen so far. It contains a transistor, a push button, two LEDS, two resistors and a battery. You're already familiar with resistors, LEDs, and push buttons.

Transistor
Like a diode, a transistor is a semiconductor device. A transistor can permit, restrict, or constrain the flow of electrons. One important capability of a transistor is that it can act as a switch, controlling the flow of electrons in a circuit. Another important capability of a transistor is that it can amplify current or voltage in a circuit. View this short video to learn a little more about transistors. https://www.youtube.com/watch?v=EACjoPZPYzI

Figure 14: Transistors



Assemble the circuit below, See 4F diagram. When you press the button do both LEDs light up? Do you notice any difference in the brightness of the LEDs?



Closure

Connect the activity to the engineering design challenge. Ask: *What did we learn today that will help us provide a recommendation to the client? How can we test our design to make sure it meets the power constraints?* **Say:** *We will continue in the Learn stage during our next class.*

4.A Client Memo 2

Dear Engineers,

Thank you for investigating the Sphero Bolt and possible cell phone capabilities that might be candidates for an electronic expansion pack. We recently decided on the power constraints to consider in your design. The electronic expansion pack will use a lithium battery to deliver 3 volts of power at a maximum current of 90 mA. Please be sure to test your electronic expansion pack designs against this constraint.

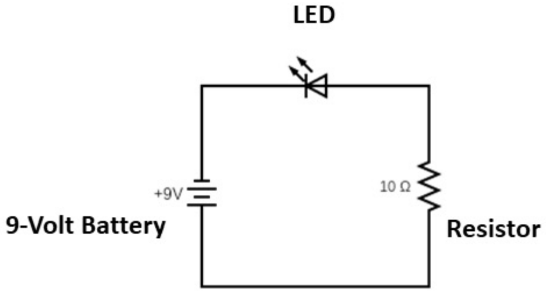
Sincerely,

Mike Rowbit

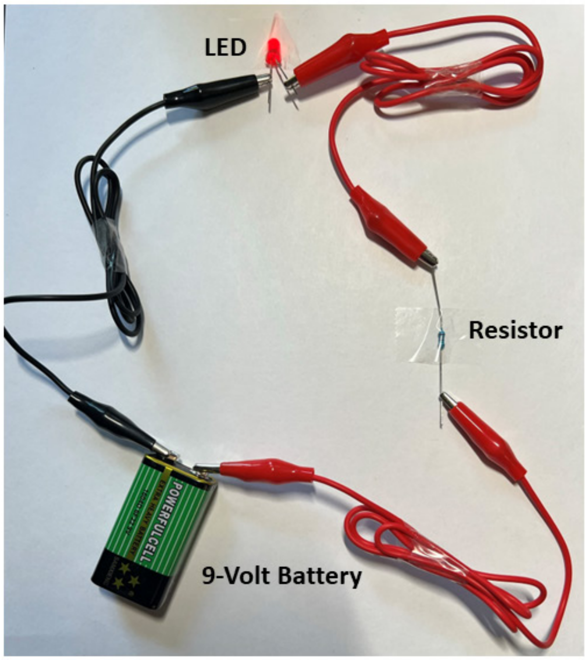
Mike Rowbit
Engineer
BLEEEP (BLossom Engineering Electronic Expansion Packs)

4.B Simple Circuit 1

Circuit 1 Schematic

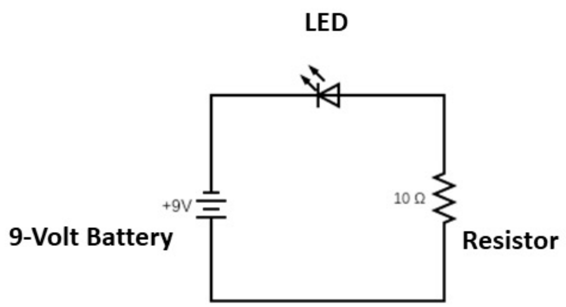


Physical Circuit 1

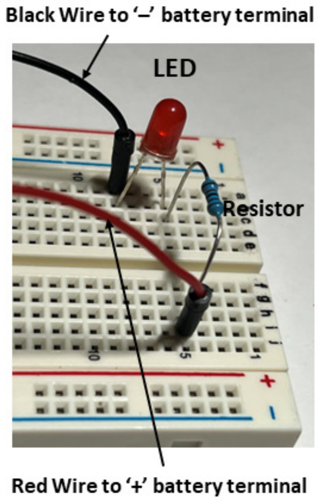


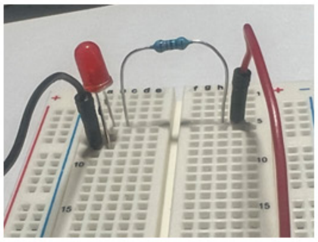
4.C Simple Circuit Breadboard

Circuit 1 Schematic

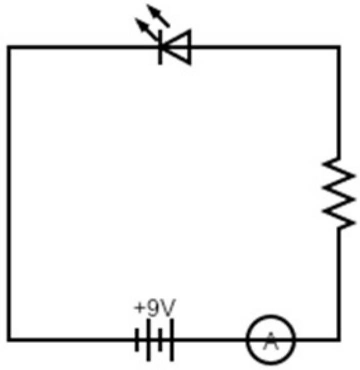


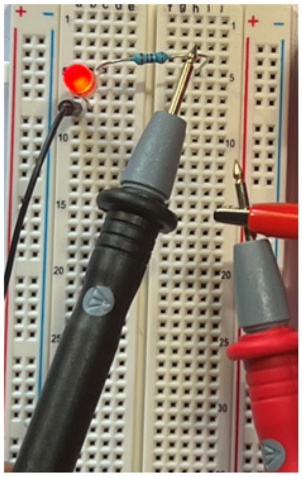
Breadboard Circuit 1



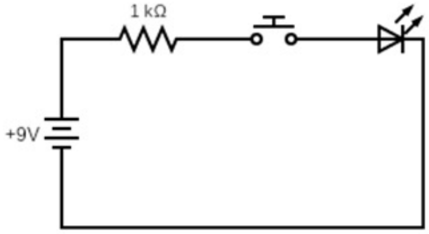


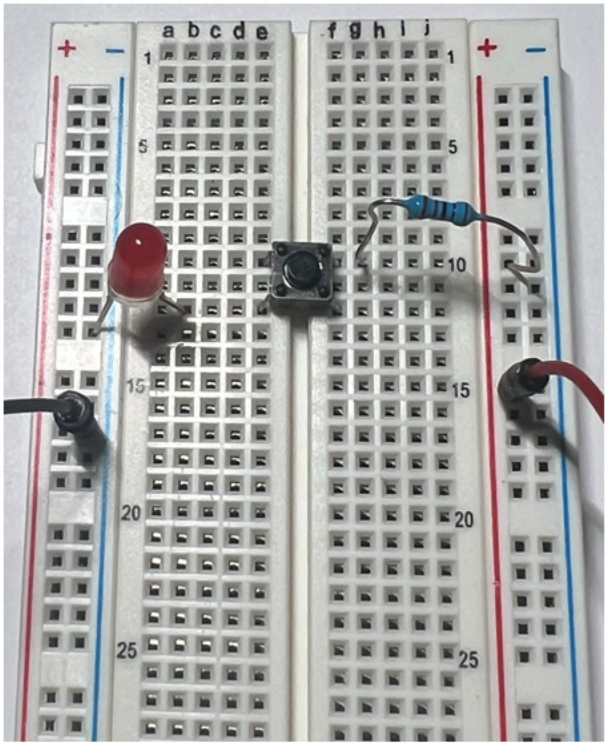
Simple Circuit 2 - Multimeter





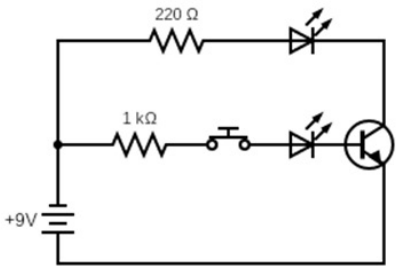
Pushbutton Switch Circuit

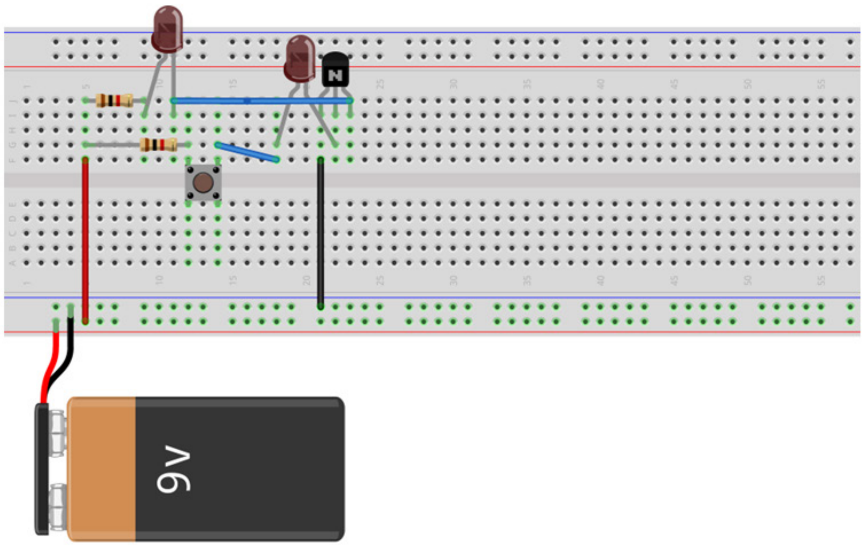


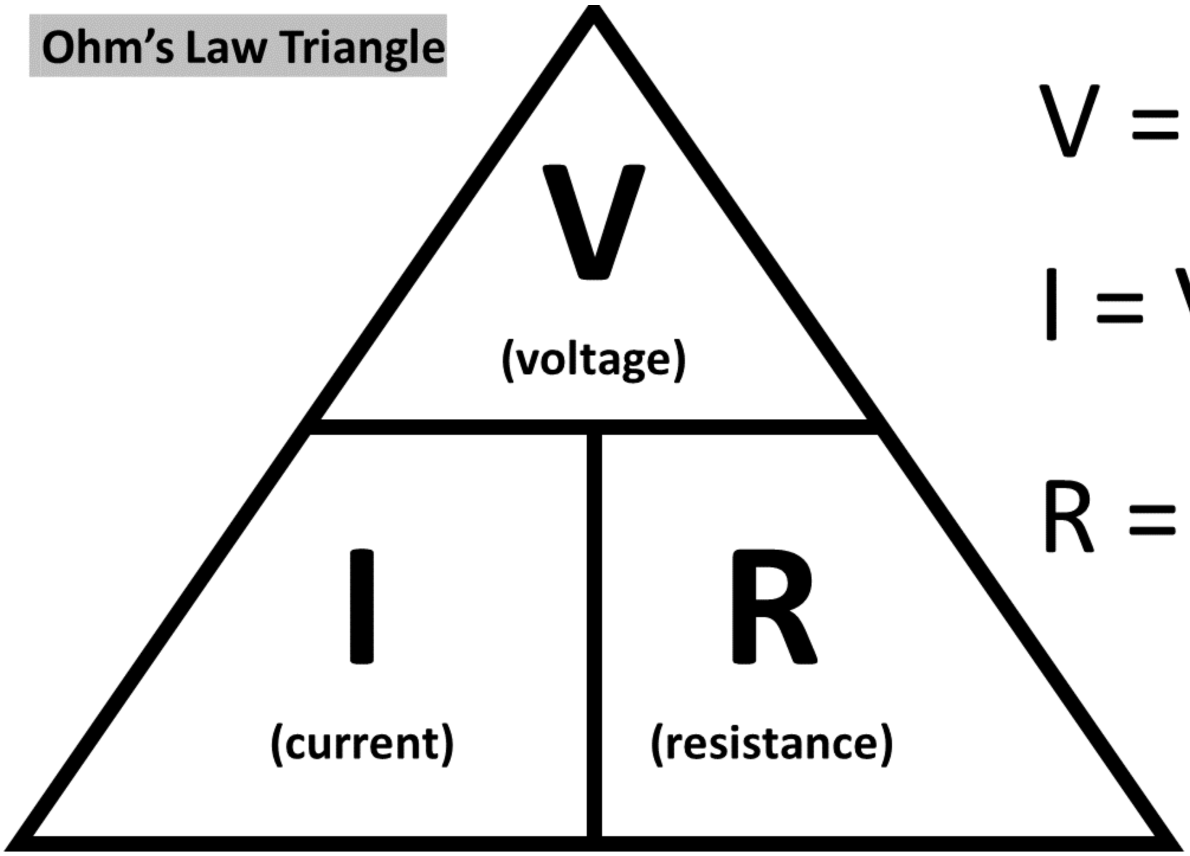


4F. Transistor Circuit

Transistor Circuit





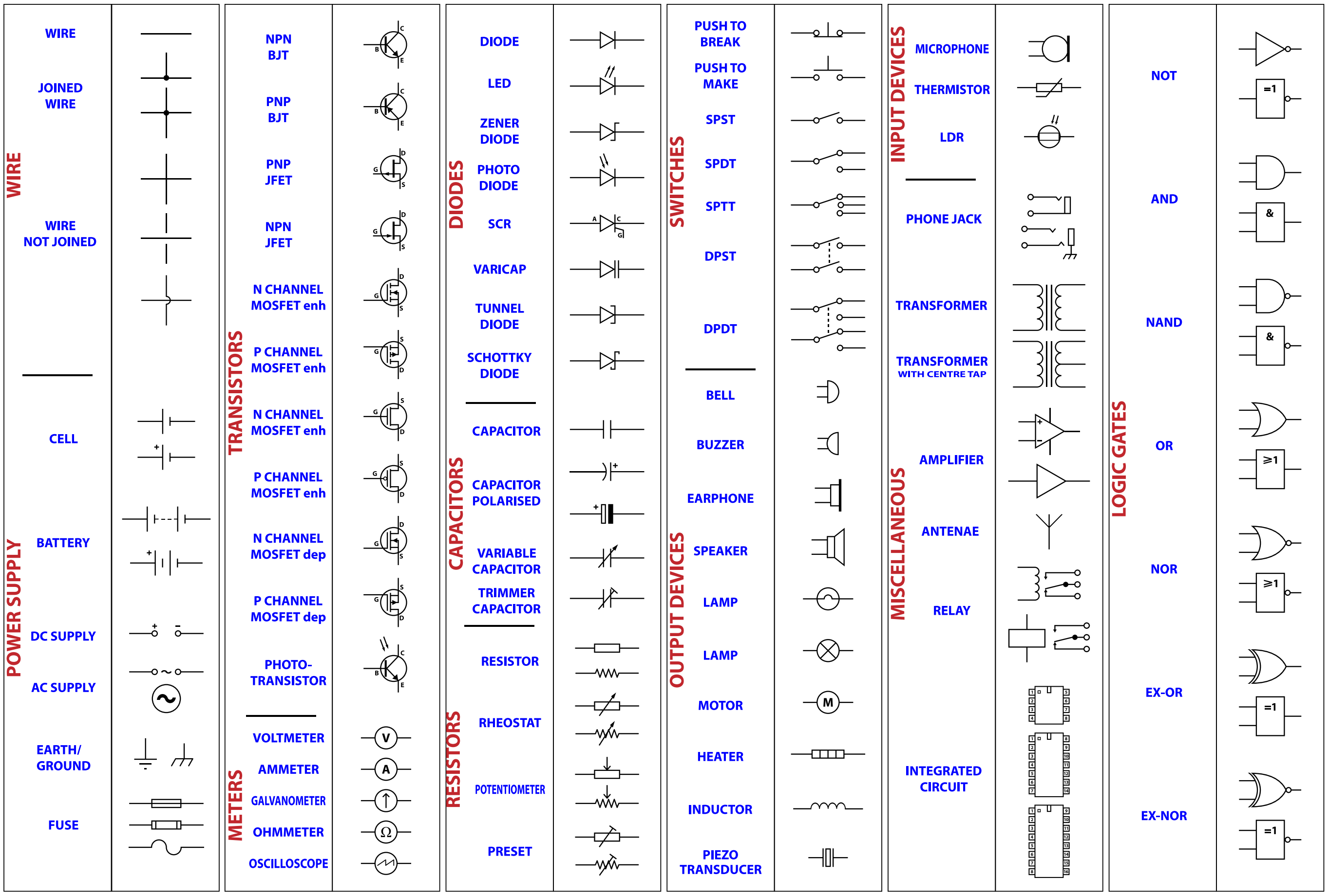


$$V = I \times R$$

$$I = V \div R$$

$$R = V \div I$$

ELECTRONIC CIRCUIT SYMBOLS



RESISTOR CODES

0	1	2	3	4	5	6	7	8	9
BLACK	BROWN	RED	ORANGE	YELLOW	GREEN	BLUE	VIOLET	GREY	WHITE

x0.01	x0.1
SILVER	GOLD

±10%	±5%	±2%	±1%
SILVER	GOLD	RED	BROWN

LESSON FIVE:

Lesson Objectives
Students will be able to:
- Distinguish between renewable and non-renewable energy sources
- Explain the impact that non-renewable energy has on the environment

Materials
Per classroom
- EDP Poster

Per student
- EDP slider and paperclip
- Laptop/Chromebook/ Tablet
- Engineering notebook

Time Required
One 50-minute lesson

Standards Addressed
- Core Standard 10
- ETE – 10.1
- ETE – 10.2
- ETE – 10.3
- ETE – 10.4

Key Terms
- energy
- renewable
- non-renewable
- green energy

Lesson Summary
Students learn about and discuss sources of electricity. They will research renewable and nonrenewable sources of energy and the advantages and disadvantages of each. This will be important as environmental considerations were listed in the client letter.

Classroom Instruction
Introduction
1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client.* Point out the “Problem” block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Say:** *Before we can start designing solutions, we need more information. Ask: What step of the engineering design process are we in?* The students should identify that they are in the “Learn” stage.
3. **Identify what students need to learn about. Say:** *In the previous lesson, you learned about electricity.* **Ask:** *What other information will you need to know in order to solve the problem?*

Activity
4. **Introduce the topic of energy. Ask:** *How can I turn the lights on in our classroom? How do we have electricity?* Facilitate a classroom discussion about where electricity comes from, and not just how it works.
5. **Split students into design teams to discuss types of energy sources.** Hand out Duplication Master 5.A Types of Energy. Within their design teams, have students brainstorm advantages and disadvantages of each type of energy. The teacher can decide if students can use their personal devices to research the topic.
6. **Discuss the energy types as a class.** Once students have finished working in teams, discuss them as a class, focusing on sharing ideas about the advantages and disadvantages.
7. **Play the “Design a Renewable Future” game.** Within design teams, students can work together to play the game provided by PBS. Students should try to achieve the highest score for the cities they choose.
   - https://www.pbs.org/wgbh/nova/labs/lab/energy/research/map/

Closure

8. **Connect the activity to the engineering design challenge.** **Ask:** *What did we learn today that will help us design another item to sell on the side of the Sphero BOLT? What considerations should we make when it comes to environmental impact of energy?* **Say:** *We will continue in the Learn stage during our next class.*

Duplication Masters

5.A Types of Energy

Educator Resources

5.B Types of Energy Answer Key

Name____ Date_______________ Period __________

5.A Types of Energy

Energy Type	Resource Needed	Resource Needed	Disadvantages
Biomass			
Coal			
Fossil Fuels			
Geothermal			
Hydrogen			
Hydropower			
Natural Gas			
Nuclear			
Solar			
Wind			

Name____ Date_______________ Period __________

5.B Types of Energy Answer Key

Energy Type	Resource Needed	Resource Needed	Disadvantages
Biomass	Organic Matter	• Renewable • Reliable • Abundant • Reduced waste	• Expensive • Requires space • Greenhouse gas emissions
Coal	Coal	• Abundant supply • Inexpensive	• Dangerous byproducts • Non-renewable • High carbon emissions
Fossil Fuels	Decomposing Plants/Animals	• Inexpensive • Efficient • Safe	• Contribution to global warming and pollution • Hazardous waste
Geothermal	Earth's Heat	• Renewable • Reliable • Highly efficient • Unlimited supply	• Expensive • Difficult to implement in big cities • Can cause greenhouse emissions
Hydrogen	Hydrogen	• Renewable • Non-toxic • Can be stored for a long time	• Can result in toxic emissions
Hydropower	Flowing Water	• Renewable • No waste produced • Can be used on a large scale	• Expensive • Impacted by drought • Can impact fish populations
Natural Gas	Rock Formations	• Safe and easy to store • Efficient • Reliable • Affordable • Abundant	• Greenhouse gas • Highly combustible
Nuclear	Uranium	• Reliable • Low operating costs • Reliable	• Expensive • Security threat • Non-renewable
Solar	Sunlight	• Renewable • Unlimited energy	• Seasonal • Expensive capital cost
Wind	Wind	• Renewable • Abundant • Can produce large amounts of power	• Unreliable, may stop without notice • Specific to windy area

LESSON SIX:

Lesson Objectives
Students will be able to:
- Utilize a microbit to construct a circuit.

Materials
Per classroom
- EDP Poster

Per group
- micro:bit
- Battery pack
- Breadboard adaptor
- Breadboard
- Servo
- Jumper wires

Per student
- EDP slider w/ jumbo paperclip
- Laptop or equivalent device
- Engineering notebook

Time Required
One 50-minute lesson

Standards Addressed
Middle School
- Core Standard 10
- ETE – 10.2
- ETE – 10.3
- ETE – 10.4
- MS-PS4-1
- MS-PS4-2

High School
- Domain – Soldering, Equipment, and Supplies Core Standard 6
- DE – 6.1
- DE – 6.2
- DE – 6.3
- DE – 6.4
- STEL 6:F

Lesson Summary
Students use the microbit and breadboard to code a servo.

Background
Teacher Background
Topic 1: Microelectronics with Microbit
- https://makecode.microbit.org/device
- https://www.youtube.com/watch?v=bYSot9bgr-o

Topic 2: Servos
- https://www.youtube.com/watch?v=tHOH-bYjR4k

Topic 3: Coding
- https://www.youtube.com/watch?v=bYSot9bgr-o

Before the Activity
Assemble kits for each team. Each kit will contain these components:
- Microbit
- Battery pack
- Breadboard adaptor
- Breadboard
- Servo
- Jumper wires

Classroom Instruction
Introduction
1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client.* Point out the “Problem” block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Say:** *Before we can start designing solutions, we need more information.* **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the “Learn” stage.
3. **Identify what students need to learn about. Say:** *You learned about Ohm’s Law and Simple Circuits in the previous lesson. Now that we understand Ohms Law and the make-up of a basic circuit lets look into using and wiring an electrical component and programming its use through micro-electronics.*

4. **Ask:** *What other information will you need to know in order to solve the problem?*

Activity

You will wire and code a servo in this lesson.

Wire the circuit

1. Gather the parts needed for your circuit as pictured in 6.A
2. Wire the circuit:
   a. Place the dragon tail on the breadboard. (Be careful when handling the breadboard adaptor as the prongs can puncture your skin.)
   b. Using 3 male-to-male jumper wires, connect 1 wire to each of the holes in the JST connector cable attached to the servo. The jumper wires do not have to be any particular color, just pay attention to which JST wire each is connected to.
   c. Attach the data wire (JST orange) to pin 1 of the breadboard adaptor.
   d. Attach the ground wire (JST brown) to the ground line on the breadboard.
   e. Attach the power wire (JST red) to the power line on the breadboard.

Code the microbit: https://www.youtube.com/watch?v=bYSot9bgr-o

1. Goto Makecode.microbit.org to access the coding environment.
2. Create a new project named "Servo_YourName", eg. "Servo_Jalena."
3. Code the microbit using the blocks as pictured in 6.B.
4. Flash the code to your microbit.
5. Disconnect the microbit from your computer.
6. Attach the battery pack to the microbit.
7. Place the microbit into the breadboard adaptor.
8. Experiment with pressing the A and B buttons. Your servo should move back and forth.

If your program is not working, check:

1. Does the programmed pin match the pin for the Servo Signal
2. Is your program correct?
3. Is your circuit complete?
4. Is the battery pack turned on?
5. Do the batteries need replacing?

Key Terms

- resistance/resistor
- voltage
- current
- capacitance/capacitor
- diode
- load
- conductors
- inductance
- transformation
- gyration
- servo
- sensors
- switch
- motor

Assessments

Students show their working circuit.

Duplication Masters

- 6.A Servo Wiring
- 6.B Servo Coding

Educator Resources

Micro:bit Educational Foundation | micro:bit (microbit.org)

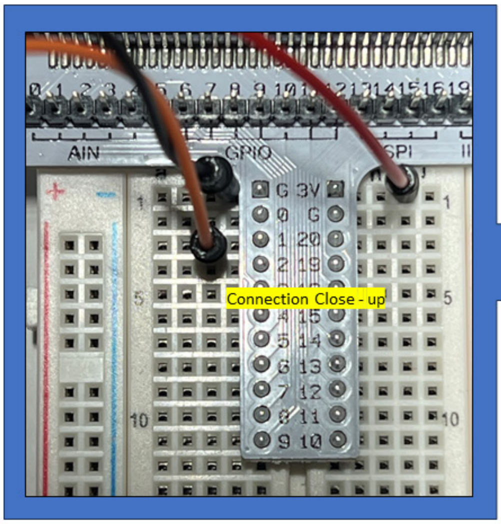
Show your instructor your working circuit.

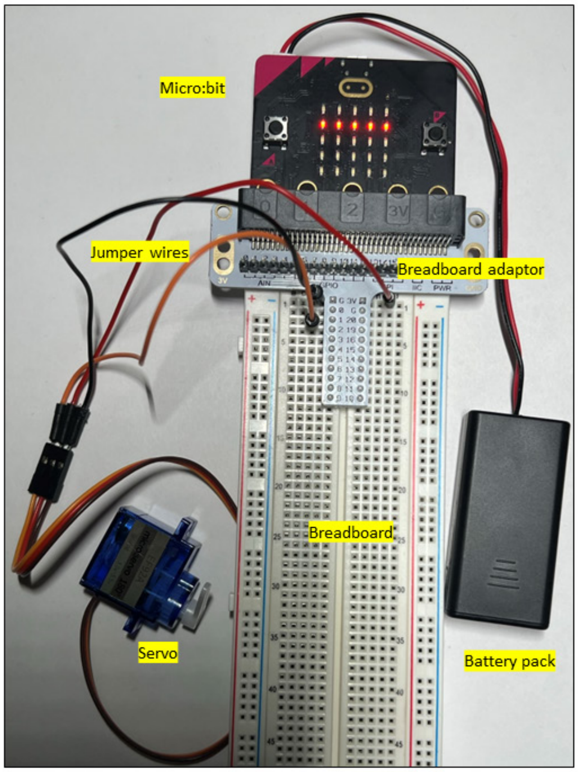
Closure

5. **Connect the activity to the engineering design challenge.** **Ask:** *What did we learn today that will help us provide a recommendation to the client? How does using a microbit in your circuit provide additional functionality over your simple circuit from the last lesson?* **Say:** *We will move to the design and build stages during our next class.*

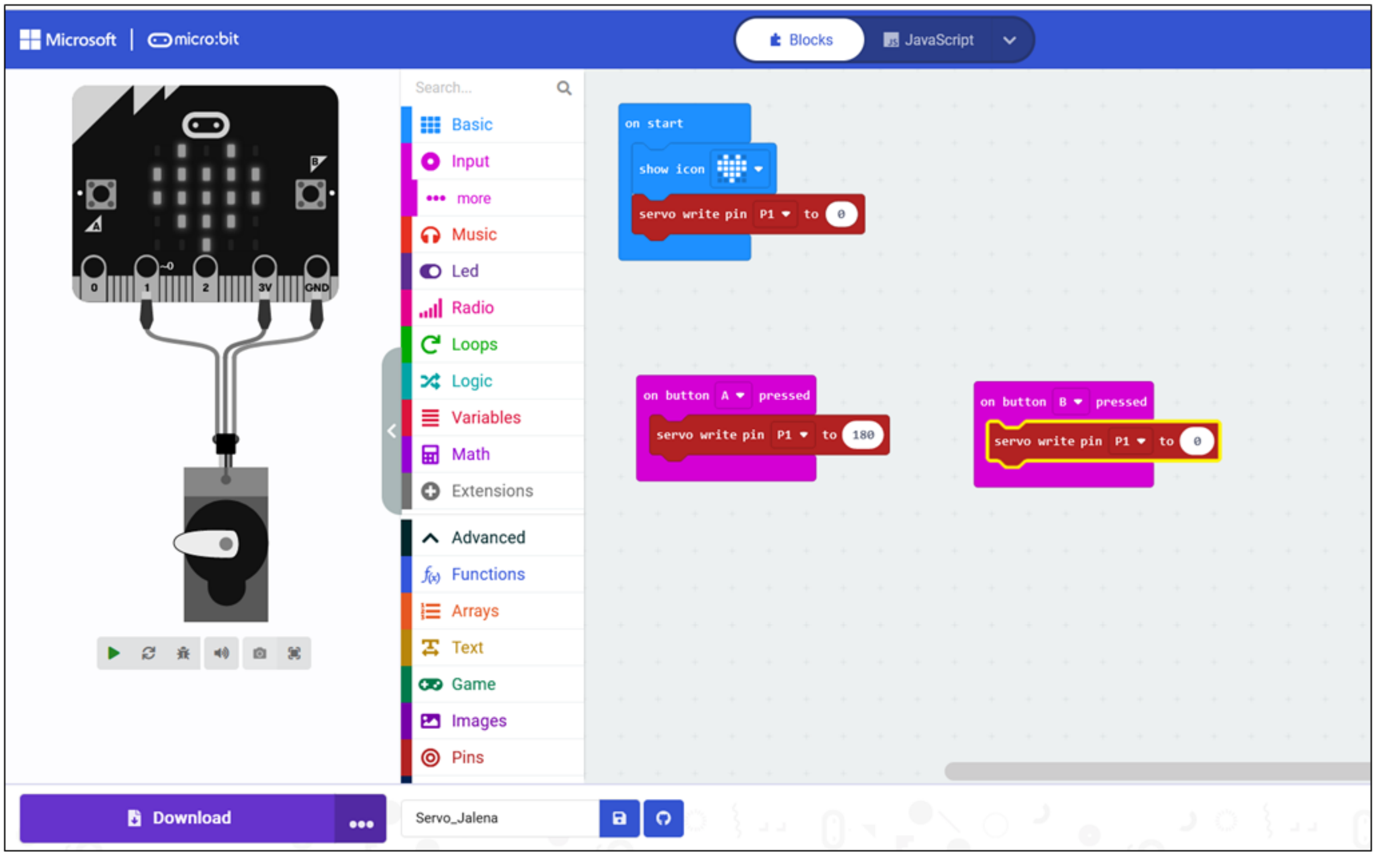
6.A Servo Wiring

Servo Wiring





Microbit Servo Code



LESSON SEVEN:

Lesson Objectives
Students will be able to:
- Design solutions to an engineering design challenge
- Create a mind map
- Brainstorm as a team
- Defend design decisions
- Sketch ideas

Materials
Per classroom
- EDP Poster

Per student
- EDP slider and paperclip
- Laptop/Chromebook/ Tablet
- Engineering notebook
- Pencils and erasers

Time Required
One 50-minute lesson

Standards Addressed
Middle School
- STEL 1:J
- STEL 1:M
- STEL 2:S
- STEL 4:M
- STEL 7:R
- STEL 7:U

High School
- STEL 1:R
- STEL 2:X
- STEL 4:R

Key Terms
- innovation
- evaluate
- mind map
- refine
- sketch
- brainstorm

Lesson Summary
Now that students have learned about the Sphero, electricity, block coding, and renewable energy, they are ready to develop their ideas into a solution to the engineering design challenge. Students will work individually and in teams to brainstorm, create mind maps, and sketch their ideas. They will converse and decide on one best electric expansion pack per team prior to the end of class.

Classroom Instruction
Introduction
1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Have students read Duplication Master 7.A Client Memo 3.** This memo will tell students that they are in the Plan stage of the Engineering Design Process (EDP).
3. **Identify where they are in the engineering design process (Plan). Say:** *So far, we have defined the problem with help from our client.* Point out the "Problem" block on the EDP poster and have students look at their EDP sliders. **Say:** *Before we can start designing solutions, we need more information.* **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Plan" stage.
4. **Identify what students need to learn about. Say:** *In the previous lesson, you learned about coding.* **Ask:** *What other information will you need to know in order to solve the problem?*

Activity
5. **Discuss tools to generate ideas for a solution. Say:** *There are different ways that engineers generate ideas to solve a problem. Mind maps, brainstorming, and sketching are tools that we can use to work toward solving the challenge. A mind map is a tool that can help organize your thoughts by grouping different ideas and concepts together. Brainstorming is the generation of ideas to work toward a goal. Sketching your ideas will help visualize the electric expansion pack so your teammates can ask questions about how it will work.*
6. **Create mind maps about potential solutions.** Hand out Duplication Master 7.B Example Mind Map. **Say:** *This is a mind map about playing soccer. When the author wanted to think about the different equipment, skills, and positions needed to play the game, they made a mind map to put their thoughts on paper.* Allow students a few moments to look at the map. **Say:**

Now, you are going to make a mind map about your electric expansion pack. Draw circles or squares around each of your thoughts, and connect them with arrows.

7. **Brainstorm potential solutions to the client's problem.** **Say:** *We are going to brainstorm individually, and then work as a group to continue brainstorming solutions to the client's problem.* Hand out Duplication Master 7.C Brainstorming Worksheet and allow a few minutes for the students to brainstorm individually. **Say:** *Using the mind map you created, brainstorm possible ideas using the chart.*
8. **Gather into pre-determined design teams to brainstorm.** **Say:** *Now that you have come up with some ideas on your own, work in your teams to review your ideas and continue coming up with new solutions.* Allow the students a few minutes to discuss.
9. **Come to a consensus on the best design in each group.** **Say:** *Within your design teams, choose your top idea that you would like to move forward with as your proposed electric expansion pack to Sphero.*
10. **Sketch top design choices.** Hand out Duplication Master 7.D Design Sketching. **Say:** *Now that you have a final design choice to pursue, sketch it out! Use the hairdryer sketch as an example of how to approach this task. Each student in your group should make a sketch so you can see if your visualizations are similar or different.* Allow students some time to sketch their primary idea.

Closure

11. **Connect the activity to the engineering design challenge.** **Ask:** *What did we learn today that will help us provide a recommendation to the client? How are mind maps helpful? Why is brainstorming important? How did sketching help explain your idea?* **Say:** *We will move to the Try stage during our next class.*

Duplication Masters

- 7.A Client Memo 3
- 7.B Example Mind Map
- 7.C Brainstorming Worksheet
- 7.D Design Sketching

7.A Client Memo 3

Dear Engineers,

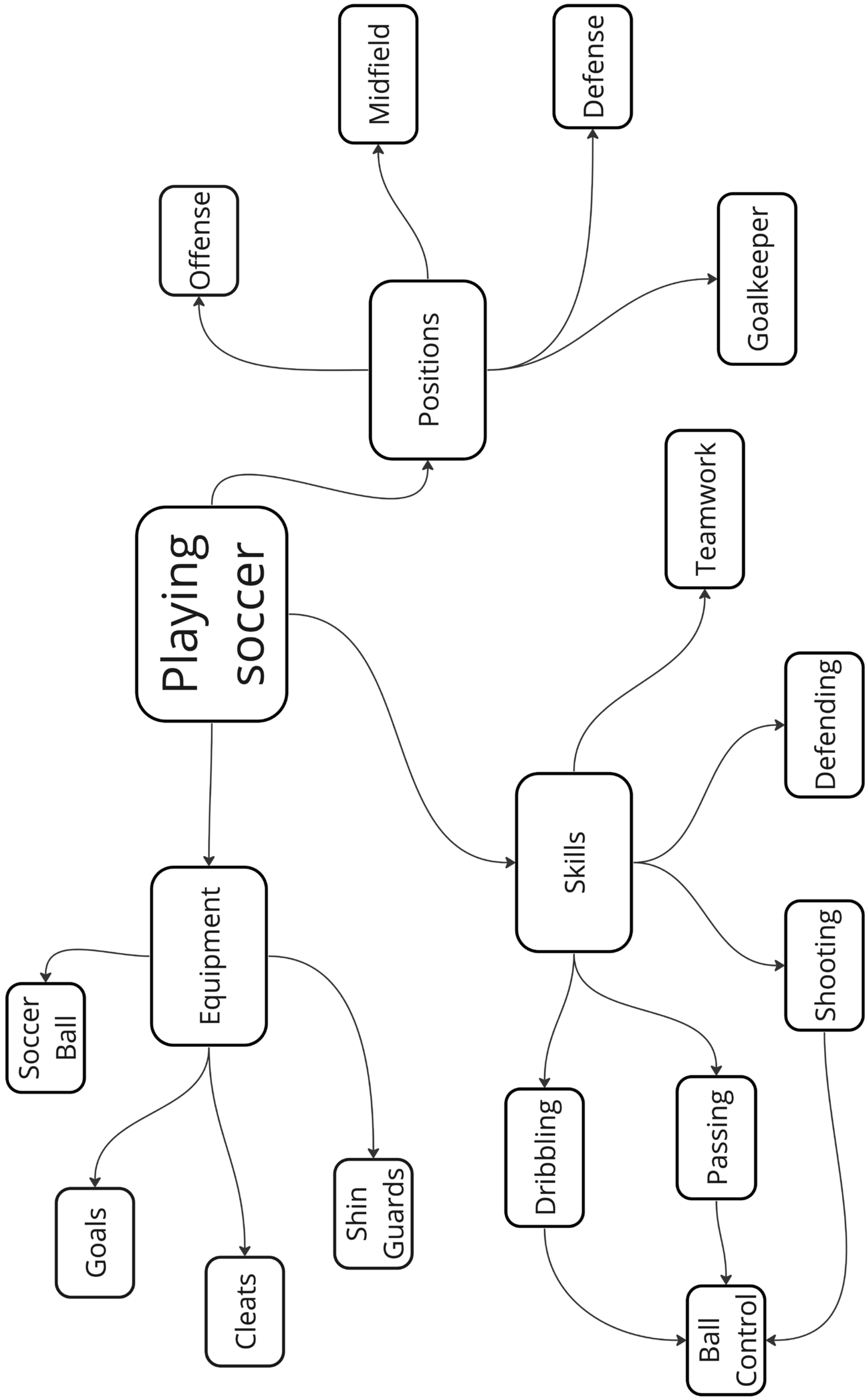
Thank you for taking the time to learn about the Sphero BOLT. Now that you have all the information you need to design a solution, it is time to enter the Plan stage. Please work in your design teams to provide a recommendation for an electronic expansion pack to the Sphero BOLT. Remember that it is important to consider environmental impact, expansion appeal, cost, and compatibility with the current Sphero BOLT design. I am looking forward to hearing your ideas.

Sincerely,

Mike Rowbit

Mike Rowbit
Engineer
BLEEP (BLossom Engineering Expansion Packs)

7.B Example Mind Map



Name____ Date_______________ Period __________

7.C Brainstorming Worksheet

Brainstorming

For each idea, ask yourself the following questions:

- What does your electric expansion pack do?
- What does it look like?
- How does it add to the Sphero's capabilities?
- Why will this be an appealing toy?

When brainstorming with your teammate(s), you get to ask the questions! Try to figure out what they are thinking about and how it will help our client with the challenge.

Idea #1:

Idea #2:

Idea #3:

Idea #4:

Idea #5

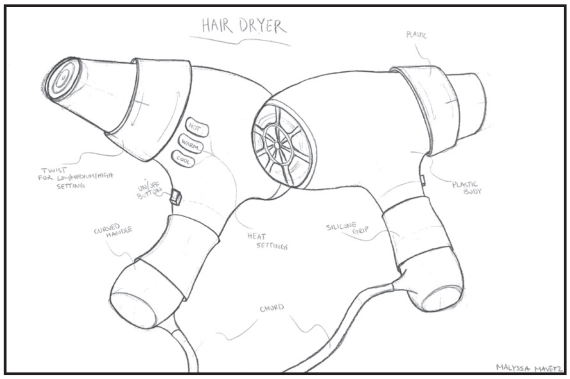
Idea #6

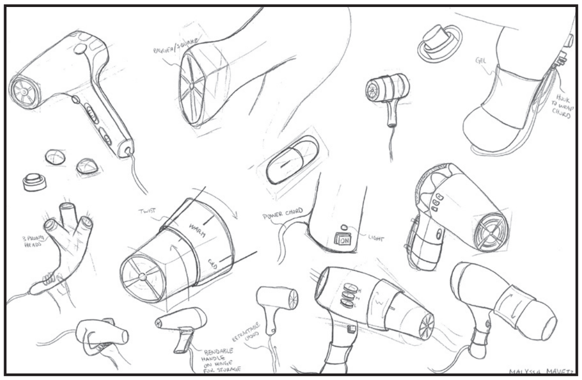
Idea #7:

Name____ Date_______________ Period __________

7.D Design Sketching

Now that you have chosen which idea will be proposed as your solution to the engineering design challenge, it is time to draw it! Make a sketch of your design in the box below. What components will there be? How does it work with the existing Sphero tool? Ensure you label components clearly.





The above images are from Malyssa Mavetz (https://malyssamavetz.myportfolio.com/). Her website has many useful ideas for designing. In particular, the concept sketches (such as the ones above) and the Lucky Charms Marshmallow Mill project in which she lays out how ideas went from brainstorming to final product.

LESSON EIGHT:

Lesson Objectives

Students will be able to:

- Create a model that represents their proposed design
- Work together within a design team
- Perform cost calculations

Materials

Per classroom

- EDP Poster

Per group

- Varies based on grade level and teacher preference, please review the "Before the Activity" section for more detail.

Per student

- EDP slider and paperclip
- Laptop/Chromebook/ Tablet
- Engineering notebook

Time Required

One 50-minute lesson

Standards Addressed

Middle School

- STEL 1:J
- STEL 1:M
- STEL 2:S
- STEL 4:M
- STEL 7:R
- STEL 7:U

High School

- STEL 1:R
- STEL 2:X
- STEL 4:R

Lesson Summary

Students will build their product designs within their teams. Depending on the grade level being taught, these builds can be true designs or simply representations of their product. Students will calculate the cost of their design based on the materials used to create it.

Background

Before the Activity

Depending on the grade level being taught, this lesson may be approached in different ways. Younger students may focus more on representative builds of their designs. For example, if they would like to add a light and speaker to the interior of Sphero BOLT, they may just use cardboard, string, and markers to make a model of how the pieces would theoretically connect to one another within the Sphero BOLT toy. If funds and time allows, older students may actually connect a small light and speaker to their Sphero BOLT. The materials that the teacher prepares for class are highly dependent on how they would like to approach the lesson.

If the teacher chooses to let students add electrical components to the Sphero BOLT, cell phone repair kits should be provided so they can properly break apart the Sphero BOLT in a way that it can be put back together by the end of class. These repair kits provide helpful tools that can break apart the Sphero BOLT in a non-destructive manner.

Once the material list is determined, the teacher will need to complete the first three columns of Duplication Master 8.A Material Cost List. Each item should have a unit and cost per unit assigned to it so that students can calculate the final cost of their product. A few examples are shown below, as well as what the student would fill out (in blue). Note that since each item may serve as a representation of an actual built item (string serves as wire), the cost should represent the true item (wire) cost.

Item	Unit	Cost per Unit	Units Used	Total Cost
Cardboard	1 square foot	$0.50	7	$3.50
String (wire)	1 foot	$1.00	4	$4.00
Motion Sensor	1 sensor	$1.00	1	$100
			TOTAL:	$107.50

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Try). Say: So far, we have defined the problem with help from our client.** Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Say:** *Before we can start designing solutions, we need more information.* **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Try" stage.
3. **Identify what students need to learn about. Say:** *In the previous lesson, you created mind maps and brainstormed as a team to come up with your final design idea, which you sketched.* **Ask:** *What other information will you need to know in order to solve the problem?*

Activity

4. **Provide an overview of how students should spend their time. Say:** *Today, you will be building your designs as a team. You have a variety of materials to choose from, but each one has a cost associated with it.* Hand out Duplication Master 8.A Material Cost List. **Say:** *As you build your design, keep in mind how much your design is going to cost. In our next lesson, we will use the cost of your product to evaluate how likely our client is to utilize it.*
5. **Allow students to gather in their design teams.** Let students spend most of the remainder of the period building their designs. You may assist as needed.

Closure

6. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us provide a recommendation to the client? What materials did you use to build your product? How much did it cost?* **Say:** *We will continue in the Test stage during our next class.*

Key Terms

- construction
- build
- cost analysis

Duplication Masters

- 8.A Material Cost List

Name____ Date_______________ Period __________

8.A Material Cost List

Item	Unit	Cost per Unit	Units Used	Total Cost

TOTAL:

Name____ Date_______________ Period __________

LESSON NINE:

Lesson Objectives
Students will be able to:
- Test a prototype
- Evaluate a prototype based on provided criteria
- Use a decision matrix

Materials
Per classroom
- EDP Poster

Per student
- EDP slider and paperclip
- Laptop/Chromebook/Tablet
- Engineering notebook

Time Required
One 50-minute lesson

Standards Addressed
- NGSS HS-ETS1-3

Key Terms
- prototype
- testing
- decision matrix

Duplication Masters
- 9.A Decision Matrix Directions
- 9.B Decision Matrix Activity

Lesson Summary

Now that students have built a model or prototype of their design, they are going to test it out. Students will evaluate their own products based on a provided decision matrix. The decision matrix lists four factors to consider when presenting their design to the client. After evaluating their own designs, teams will brainstorm how they can improve their score, therefore improving their product.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Test).** Point out the “Problem” block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Say:** We have built our designs and tried making a model of them. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the “Test” stage.

Activity

Classrooms that Built Models

3. **Allow students to gather in their design teams.** Students will be working within their teams to evaluate their design.
4. **Explain the decision matrix activity. Say:** *We are going to use a decision matrix to determine if your designs will be successful.* Hand out Duplication Master 9.A Decision Matrix Directions. **Say:** *Using the decision matrix, evaluate your team’s design and come up with a final score.*
5. **Allow the students time to complete the matrix.** Hand out Duplication Master 9.B Decision Matrix Activity. The teacher should walk around the room and answer any questions the students may have about the decision matrix and how to use it.
6. **Brainstorm ways to improve the overall score. Say:** *Now that you have scored your design, think about what you could do to improve your score. What category did you score the lowest? How could you change your design to increase that score?* Allow the groups some time to brainstorm.

Classrooms That Built Prototypes

3. **Allow students to gather in their design teams.** Students will be working within their teams to test their design.
4. **Explain the activity. Say:** *Today, you are going to test your prototypes and evaluate them based on provided criteria.* Hand out Duplication Master 9.A Decision Matrix Instructions. **Say:** *Each of the categories in the decision matrix will be used to evaluate your design.*
5. **Allow students time to test their products and complete the matrix.** Hand out Duplication Master 9.B Decision Matrix Activity. Students should use the majority of class time testing their products alongside their Sphero while evaluating themselves according to the provided criteria.
6. **Brainstorm ways to improve the overall score. Say:** *Now that you have scored your design, think about what you could do to improve your score. What category did you score the lowest? How could you change your design to increase that score?* Allow the groups some time to brainstorm.

Closure

7. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us provide a recommendation to the client?* **Say:** *We will continue in the Decide stage during our next class.*

9.A Decision Matrix Directions

A decision matrix is a tool that evaluates and prioritizes your options to help you make the best decision for your client. The row represents your prototype, which will be evaluated for each of the four column headings. The four column headings represent important factors to consider when making your recommendation to the client. For this decision matrix, each factor will be rated on a scale from 1 to 5. A rating of 1 indicates that the design does not meet expectations for the category, while a rating of 5 indicates that the design exceeds expectations for the category. An explanation of each category is given below.

Category	Explanation	A rating of 1 indicates...	A rating of 5 indicates...
Compatibility	*How easy is it to incorporate your design into the Sphero?* *Is the product physically attached to the Sphero BOLT (lower rating) or a separate piece (higher rating)?* *Will extra programming, coding, or electronic pieces be required?*	*Very difficult to incorporate the design into the Sphero*	*Very easy to incorporate the design into the Sphero*
Environmental Impact	*Does the design require extra power?* *Are the materials easy or difficult to harvest?*	*Negative impact on environment*	*No impact on environment*
Appeal to Users	*Will this design cause students to want to use the Sphero longer?* *Does the design increase the desirability of the tool?*	*Is not interesting to students learning STEM*	*Is very interesting to students learning STEM*
Cost of Design	*How much does the design cost?* *Is it expensive or affordable?*	*Low cost*	*High cost*

Name_______________________________________ Date_______________ Period __________

9.B Decision Matrix Activity

Evaluate your product for each of the four categories. Afterward, brainstorm possible ways to improve your score by making small changes to your design.

	Compatibility	**Environmental Impact**	**Appeal to Users**	**Cost of Design**	**Total**
Product:					

How can you improve your score in:

Compatibility

Environmental Impact

Appeal to Users

Cost of Design

LESSON TEN:

Lesson Objectives

Students will be able to:

- Communicate science, technology, engineering, and mathematics ideas by giving presentations
- Use evidence-based reasoning to support their engineering decisions

Materials

Per classroom

- EDP Poster

Per student

- EDP slider and paperclip
- Laptop/Chromebook/ Tablet
- Engineering notebook

Time Required

Two 50-minute lessons

Standards Addressed

- NGSS HS-ETS1-3

Key Terms

- criteria
- constraint
- decision matrix
- communication
- evidence-based reasoning

Lesson Summary

In this lesson, students will report out their group findings to provide a holistic, evidence-based recommendation to the client as a class. Students will prepare presentations as a team to share their design with the class. Students will review one another using the decision matrix prior to providing a final recommendation to the client.

Background

Teacher Background

In this lesson, students will be making presentations to convince the client that their sensor is the best option, or if they recommend the client does not choose their sensor. The teacher can choose from a variety of presentation options based on the materials and technology that are available. Presentations may be live, video recorded, or use any other technology resources available. Alternatively, the teacher may choose to have students write a letter to the client that includes the same information that would be included in the presentation. This lesson is structured to allot one class period for preparation and one for presentation and conclusion, but this should be adjusted to meet the needs of the class.

Before the Activity

- The teacher may choose to provide a presentation template to the students to save time, allowing them to focus more on content than on presentation aesthetics.
- Before distributing Duplication Master 10.E Client Memo 5, it is recommended that the teacher adds feedback specific to the students' presentations. If the teacher wants to do this, they will need to treat 10.E Client Memo 5 as a template and make a new version. They will add feedback specific to the students after the first sentence of the body of the letter.
- After students complete their presentations, the teacher will evaluate their designs based on the 10.B Client Communication Requirements document. NOTE: Although some students thrive on competition, it can have a negative impact on the engagement of other students. The teacher will need to decide on the level of competition based on their students.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Say:** *We are almost done with solving this engineering design challenge! Can anyone tell me about the problem? Who is our client? What problem do they want us to solve? What are the criteria and constraints of the problem?*
2. **Identify where they are in the engineering design process (Decide).** Point out the “Problem” block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* **The students should identify that they are in the “Decide” stage.**

Activity

3. **Read Duplication Master 10.A Client Memo 4. Ask:** *What is the client asking us to do?* (Prepare a presentation and a written document to convince the client and the rest of the class which design is best.)
4. **Explain what needs to be included in the presentation.** Hand out Duplication Master 10.B Client Communication Requirements. Briefly describe what is required. Share the presentation options that are available to students. If the teacher has developed a template for students, they should distribute it now. Note that approximately six slides should be included in the presentations:
    - Introduction of Students
    - Problem Summary
    - Importance of STEM education and student interest
    - Summary of Design
    - Test Results
    - Recommendation to Client
5. **Prepare design review presentations.** Allow students time to finish preparing for their presentations (e.g., creating visuals, filming video, rehearsing scripts, etc.).
6. **Use the decision matrix to assess design recommendations.**
7. **Prepare a class report to the client.** This is the final deliverable which must include the formal recommendations to the client with scientific justification behind the choice.
8. **Identify where they are in the engineering design process (Communication). Ask:** *What stage of the engineering design process are we in now?* Facilitate a discussion about why communication with the client is vital to engineering design.

Duplication Masters

- 10.A Client Memo 4
- 10.B Client Communication Requirements
- 10.C Decision Matrix Directions
- 10.D Decision Matrix Activity
- 10.E Client Memo 5
- 10.F Content Post-Assessment

Educator Resources

10.G Content Post-Assessment Key

Assessments

Pre-Activity Assessment

Class discussion about what is important in a presentation.

Activity Embedded Assessment

Presentation planning sheet.

Post-Activity Assessment

Final presentation assessed using 10.B Client Communication Requirements.

Closure

9. **Revisit engineering design challenge.** Discuss the client, the problem, what information led to their informed decision, and how criteria and constraints were included in the decision-making process.
10. **Provide feedback from the client.** Read Duplication Master 10.E Client Memo 5 as a class. Reflect on the engineering design process and how the process was used throughout the unit.
11. **Complete Duplication Master 10.F Content Post-Assessment.**
12. **OPTIONAL: Review the entire unit.** If time allows, the teacher may choose to review some of the material during the Learn lessons.

10.A Client Memo 4

Dear Engineers,

Thank you for your hard work in developing Sphero BOLT electronic expansion pack designs. As you finalize your decision, I would like each team to prepare a presentation describing your design, your evaluation of it, and whether or not you would recommend the design. This is your opportunity to convince the other design teams that your design is the best, so please ensure you use the guidelines I have attached when preparing your presentation.

Each team should also prepare a written document with the same details as their presentation. This is your chance to convince ME that your design is the best!

Sincerely,

Mike Rowbit

Mike Rowbit
Engineer
BLEEP (BLossom Engineering Expansion Packs)

10.B Client Communication Requirements

- Students introduce themselves.
- Students summarize the client's problem including criteria and constraints.
- Students explain why it is important to have STEM education tools.
- Students describe their solution to the problem:
    - Describe the electronic expansion pack.
    - Explain the test results they found in lesson nine.
    - Provide a recommendation to the client about their design.
- Students show data and evidence gathered and used in their design.
- Students justify their decision using data and evidence.
- All team members have a role in the presentation.
- Students demonstrate in-depth knowledge of their electronic expansion pack.

10.C Decision Matrix Directions

A decision matrix is a tool that evaluates and prioritizes your options to help you make the best decision. The row represents your prototype, which will be evaluated for each of the four column headings. The four column headings represent important factors to consider when making your recommendation to the client. For this decision matrix, each factor will be rated on a scale from 1 to 5. A rating of 1 indicates that the design does not meet expectations for the category, while a rating of 5 indicates that the design exceeds expectations for the category. An explanation of each category is given below.

Category	**Explanation**	**A rating of 1 indicates…**	**A rating of 5 indicates…**
Compatibility	*How easy is it to incorporate your design into the Sphero?* *Is the product physically attached to the Sphero BOLT (lower rating) or a separate piece (higher rating)?* *Will extra programming, coding, or electronic pieces be required?*	*Very difficult to incorporate the design into the Sphero*	*Very easy to incorporate the design into the Sphero*
Environmental Impact	*Does the design require extra power?* *Are the materials easy or difficult to harvest?*	*Negative impact on environment*	*No impact on environment*
Appeal to Users	*Will this design cause students to want to use the Sphero longer?* *Does the design increase the desirability of the tool?*	*Is not interesting to students learning STEM*	*Is very interesting to students learning STEM*
Cost of Design	*How much does the design cost?* *Is it expensive or affordable?*	*Low cost*	*High cost*

Name________________________________ Date______________ Period __________

10.D Decision Matrix Activity

Team Name	Compatibility	Environmental Impact	Appeal to Users	Cost of Design	Total

10.E Client Memo 5

Dear Engineers,

I received your presentations and final report this morning and have reviewed them. The design you recommended will be extremely helpful in encouraging student participation in STEM learning.

Thank you for your dedication to this engineering design challenge and for all of the hard work that you did for my company. I hope to have the opportunity to work with you again in the future.

Sincerely,

Mike Rowbit

Mike Rowbit
Engineer
BLEEP (BLossom Engineering Expansion Packs)

Name____ Date________________ Period ___________

10.F Content Post-Assessment

1. What is a robot?

2. What are the contents of the Sphero BOLT?

3. Write the equation for Ohm's Law.

4. What does resistance mean in the context of electricity?

5. Briefly explain how electricity works.

6. Define the term "renewable energy".

Name____ Date_______________ Period __________

10.F Content Post-Assessment

7. What does the term “microelectronics” mean?

8. Provide two examples of what a micro:bit can do.

9. How are microelectronics used in engineering and technology?

10. What jobs would you be interested in that use microelectronics? Provide one example of how microelectronics is used in that job.

10.G Content Post-Assessment Key

1. What is a robot?

   Answers will vary, and it is the teacher's direction what should receive credit.

2. What are the contents of the Sphero BOLT?

   The Sphero BOLT has LEDs, an IMU, encoders, a circuit board, batteries, processor, and motors.

3. Write the equation for Ohm's Law.

   V = I * R or Voltage = Current * Resistance

4. What does resistance mean in the context of electricity?

   Resistance is an opposition to the flow of current in an electrical circuit.

5. Briefly explain how electricity works.

   Electricity is the flow of electrical charge. It is generated through the movement or accumulation of electrons.

6. Define the term "renewable energy".

   Renewable energy is energy that is generated from renewable resources, or resources that are naturally replenished on a human timescale.

10.G Content Post-Assessment Key

7. What does the term “microelectronics” mean?

Student answers may vary, but the formal definition of microelectronics is the design, manufacture, and use of microchips.

8. Provide two examples of what a micro:bit can do.

Answers will vary, but correct answers include telling time, counting steps, programming a task, etc.

9. How are microelectronics used in engineering and technology?

There are many answers to this question, but examples include computers, electric vehicles, or circuitry.

10. What jobs would you be interested in that use microelectronics? Provide one example of how microelectronics is used in that job.

Students answers will vary based on interest. Credit may be given as long as at least one job example is provided with their logic behind how that job uses microelectronics.