Lesson 15: Circuits and Physical Prototypes

Overview

In preparation for this chapter's final project, students will learn how to develop a prototype of a physical object that includes a Circuit Playground. Using a modelled project planning guide, students will learn how to wire a couple of simple circuits and to build prototypes that can communicate the intended design of a product, using cheap and easily found materials such as cardboard and duct tape.

Purpose

The goal of this lesson is both to model for students how thinking about the physical design of a product impacts the prototyping process, and to introduce a handful of practical skills that will make creating their final projects easier.

Assessment Opportunities

1. **Create and debug simple circuits**

   Code Studio: See rubric on bubble 7. Note that you will need access to the student's physical prototype for this assessment.

2. **Develop an interactive physical protype that combines software and hardware**

   Code Studio: See rubric on bubble 12. Note that you will need access to the student's physical prototype for this assessment.

3. **Consider the needs of diverse users when designing a product**

   Wrap Up: Students should identify multiple target users and how different features of the design might impact them.

Standards

Full Course Alignment

CSTA K-12 Computer Science Standards (2017)

- ▶ **AP** - Algorithms & Programming
- ▶ **CS** - Computing Systems
- ▶ **IC** - Impacts of Computing

Objectives

Students will be able to:

- Consider the needs of diverse users when designing a product
- Create and debug simple circuits
- Develop an interactive physical protype that combines software and hardware

Preparation

- Gather prototyping materials, such as:
  - Structural material (cardboard, construction paper, etc)
  - Connective material (tape, glue, hot glue, etc)
  - Construction tools (scissors, staplers, etc)
  - Other materials (cups, binder clips, paper plates, etc)
- Prepare circuit wiring materials, such as:
  - Alligator clip wires (included in Circuit Playground classroom kit)
  - LEDs (included in Circuit Playground classroom kit)
  - Other conductive material (wire, paper clips, foil, etc)
  - (optional) Buttons or switches
- Print a copy of the project guide for each group of 2-3 students
- Prepare a model button to show the class

Links

Agenda

Warm Up (5 minutes)
Designing a Physical Device

Activity 1 (25 minutes)
Introducing the Smart Bike

Activity 2 (75 minutes)
Building the Prototype

Activity 3 (25 minutes)
Adding Inputs

Wrap Up (5 minutes)
Sharing Designs

Heads Up! Please make a copy of any documents you plan to share with students.

For the teachers

- **CSD Unit 6 - Physical Computing** - Slides
- **Circuits and Buttons** - Resource

For the students

- **How Computers Work: Circuits & Logic** - Video (**Download**)
- **Physical Prototyping** - Project Guide

Vocabulary

- **Circuit** - A device that provides a path for an electric current to flow, often modifying that current. In computers, circuits allow for simple logical and mathematical operations using electricity.
- **Prototype** - A first or early model of a product that allows you to test assumptions before developing a final version.

Introduced Code

- `createButton(pin)`
- `createLed(pin)`
- `digitalWrite(pin, value)`
- `pinMode(pin, mode)`

Teaching Guide

Warm Up (5 minutes)

Designing a Physical Device

Prompt: If you could create any kind of computational device, what would it be? What would it do? How would people interact with it?

Discussion Goal

The point of this short discussion is to get students thinking about how we might use a board like the Circuit Playground as part of a larger computing device. It's not important that we're able to completely replicate student's ideas with the board, but that we can start thinking about where the board could be used and where we might need to add additional functionality.

Share: After a few minutes of thinking time, have students share their ideas.

Discuss: How might a device like the Circuit Playground help us design and prototype some of these ideas? Consider picking a couple of ideas to put up on the board and list with the class which things features of a given device could be replicated with an element of the board, and which might require additional hardware.

Activity 1 (25 minutes)

Introducing the Smart Bike

Group: Place students into groups of 3-4.

Distribute: Give each group a copy of the project guide, and introduce the project. Give students a moment to look over the guide. This guide is similar to the one they will be using for their own final projects, but it's already been mostly completed, which allows for them to focus on how to implement the idea, instead of what the idea should be.

Discussion Goal

Students should be able to identify that almost all of the functionality (such as blinking lights, responding to button presses, and buzzing) can be done with the Circuit Playground as is. The major barrier we want to identify is how the physical requirements of the plan (such as placing the blinker lights on the ends of the handlebars) would require adding new hardware to the board. This is intended to tee up the next activity, in which students wire additional circuits onto their boards.

Discuss: Focusing on the description and sketch on the first page, how might we use the Circuit Playground to develop this prototype. Which elements are we currently *unable* to replicate with the board?

Display: Watch **How Computers Work: Circuits & Logic**.

1 **Video: Circuits and Logic**

Remarks

> The elements of our Circuit Playground are all made up of circuits so small that we can't even see most of them, but you can create a simple Circuit on your own by attaching wires to the copper pads on the edge of the board.

Distribute: Wires, LEDs, and any other hardware you want available for this portion. Let the class know that before digging too far into building our prototypes, we'll need to learn how to add additional hardware to the board.

Transition: Head to Code Studio to work on the Simple Circuits and Blinkers sections.

2-5 Simple Circuits

2 3 4 5

6-8 Smart Bike - Blinkers

6 7 8

Assessment Opportunity

Level 7: You can use this level as a formative assessment for students. Click inside the level to view a rubric and leave feedback to your students

Activity 2 (75 minutes)

Building the Prototype

Transition: At this point students should have put together the two additional LED circuits necessary for their turn signals. Now we're going to transition off of the computers for a bit to work on building that circuit into a physical prototype.

Teaching Tip

Sharing Boards? If you are sharing boards among multiple classes, you'll need to take that into consideration before groups start to build their projects. You may want to add a design constraint that the board must be easily removable from the design, or to create group sizes large enough to ensure that each group in every class has access to a board at all times.

Distribute: Make available any remaining building materials that you've gathered, such as cardboard and tape.

Build: Allow groups some time to build their prototypes, using the board and LED circuits. While there's a lot of potential functionality that we could build at this point based on the guide, make sure that students are focusing on making the turn signals work.

Teaching Tip

To provide more student ownership and creativity, consider allowing students to modify the form (but not necessary functionality) of the smart bike controller. For example, they may want to turn it into something that the rider could wear, or something that works on skateboards or other modes of transportation. The import element here is that we work in a form that requires adding additional circuits to the board, instead of continuing to work solely within the contrainsts of the board's form.

Test: Once the basic prototype is built, have students test the code they wrote. It's not uncommon at this point to see new bugs that weren't present when testing the software alone. Encourage students to test all elements of their new circuits, ensuring that all of the connection points are solid, that the circuits are connected to the correct pins, and that the LEDs are oriented correctly.

Activity 3 (25 minutes)

Adding Inputs

Display: Put up the sketch on the first page of **Physical Prototyping - Project Guide** where the whole class can see it. The first prototype that we've constructed takes care of the turn signals, but now we're going to focus on the "horn" feature. Clearly we can use the buzzer to make the horn sound, but how can we control the horn?

Transition: Send students back to the online progression to learn about creating button circuits, which they will then add to their smart bike prototypes. This portion of the progression will take them all the way through finalizing their designs and submitting the code.

9 **Button Circuits**

10-12 **Finish the Prototype**

10 11 12

Assessment Opportunity

Level 12: You can use this level as a formative assessment for students. Click inside the level to view a rubric and leave feedback to your students

Wrap Up (5 minutes)

Sharing Designs

Share: Give each group an opportunity to share their designs. Take some time to notice and celebrate the differences in design - even in a situation where we are all working from the same plan, each individual will bring their own experiences and perspectives to the design of a product.

Discuss: Using some of the specific design choices as an example, discuss with the class how their design choices impact the usability of their products. What assumptions did we make about our users, and how might our design choices have excluded or disadvantaged different user groups.

Assessment Opportunity

This discussion is intended to tie the physical design work students are doing now to the work they did in unit 4. Though we haven't asked students to spend the same amount of energy thinking about users and their needs in this project, it's still an essential element of good design. Push your students to consider how the design of *physical* computing devices brings new challenges and opportunities when it comes to designing for a diverse set of users. Students may consider how age, eyesight, or hearing may impact the usability of this design.