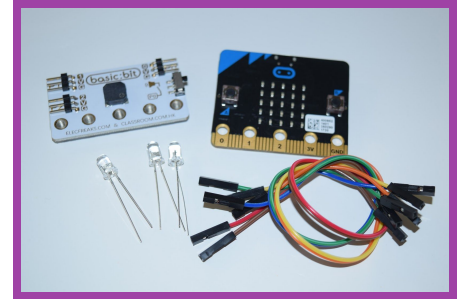


Color Mixing | Teacher Notes

Introduction

This activity explores how red, green, and blue light can be combined to make different colors. Along the way, students will learn how to control the brightness of an LED and a little bit about how color vision works.



Goal

Students will create a color mixing device that explores additive color mixing. Students will also explore how blinking lights, brightness, and their own eyes all participate in the way we see color.

Materials needed:

- micro:bit
- Small cardboard box
- White paper (printer paper, tissue, white coffee filter, etc.)
- Red, Green, and Blue LEDs with built-in resistors (available from SparkFun)
- Means of connecting the LEDs to the micro:bit such as:
 - Six alligator clips
 - An extension board with connection pins and six female-to-female jumpers
- Craft knife (*note: intended for older children who can use a sharp craft knife safely; younger children can use scissors*)

Procedure

Background Knowledge & Introduction

- Ask students what they know about colors and color mixing. Here are some suggestions for questions:
 - What does RGB stand for?
 - What happens when you mix colors? What does red and green make?
 - What connections can you make to programs like photoshop or other paint editor programs?
- Explain to students that they will be creating their own color mixing device! They will use three different LEDs to mix colors. This may also be a moment to discuss the difference between mixing paint colors and light colors.

Getting Set Up

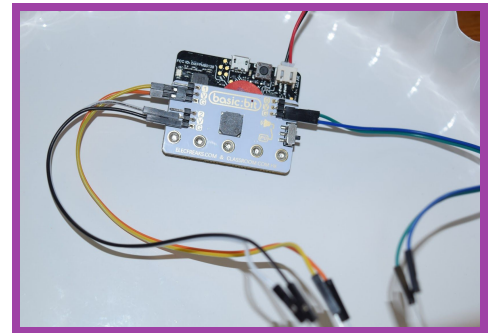
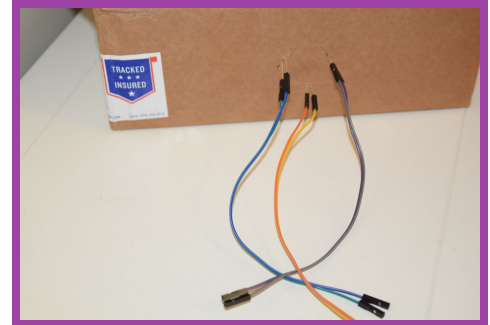
On the inside of a box, mount three LEDs with their lenses pointing towards the opposite side of the box. One way to do this is to make a short slit with the craft knife for each LED, poke its legs through the slit, and connect the jumper wires or alligator clips to its legs on the outside.

On the opposite side of the box, affix a white piece of paper or an index card to the box. This will serve as the screen that you will use to mix your lights.

Connect the LEDs to the micro:bit. The short leg of each LED should be connected to GND. The long legs should be connected as follows:

- Red LED - pin 0
- Green LED - pin 1
- Blue LED - pin 2

To figure out which LED is which, first connect its long leg to 3v. You'll see the paper light up with its color. Then connect that LED to the pin listed above. Start MicroBlocks and connect your micro:bit.



Activity 1 | Mixing Light Colors

This block turns on the red LED:

set digital pin 0 to

You should see a red glow on the side on your box. Some LEDs have a clear lens that will project a round circle of red light. Other LEDs have a milky lens that creates a more diffused glow.

This block turns off the red LED:

set digital pin 0 to

Those blocks can be used to turn the green and blue LEDs on and off by changing the pin numbers to 1 and 2. We can explore combinations of colors using a script like this:

forever

set digital pin 0 to

set digital pin 1 to

set digital pin 2 to

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Start this script, then click on the gray circle in the block to turn the LEDs on and off in different combinations. You may need to adjust the angle of your LEDs so that the circles of light will overlap.

Explore different combinations with students. What colors do you get when the red and green LEDs (pins 0 and 1) are on and blue (pin 2) is off? How about red and blue or green and blue? The colors red, green, and blue are called the primary colors for light. Combining pairs of primary colors create the secondary colors for light like yellow, cyan (blue-green), and magenta (purple). What color do you get when all three LEDs are on?



Teaching Note: color mixing with light is called "additive color mixing" because each color adds new colors to the light that reaches your eyes. In contrast, when you mix colored paints, each paint removes, or subtracts, some colors from the light that is reflected from the paint. Thus, mixing paints is called "subtractive color mixing." For more information, see https://en.wikipedia.org/wiki/RGB_color_model.



Activity 2 | Controlling Brightness

In the last activity, each LED was either completely on or off. We could control which LEDs were on, but not how bright they were. We could only create seven different colors of light: red, green, blue, yellow, cyan, and magenta (plus black when all LEDs are off). If we can control how much of each color we add by controlling the brightness of each LED, we can create a wider variety of colors!

However, the micro:bit only has "digital" output pins. This means they can only be on or off and not in between. In electrical terms, a digital pin can output zero volts or 3v but not any voltage in between.

Fortunately, we can take advantage of how our eyes work to simulate brightness. Our eyes perceive a rapidly blinking light as if it were a steady glow (a concept explored in the Time Scales activity found here: <http://bit.ly/2JCUTTf>). What's more, our eyes average the amount of light they receive over a short period of time to create our perception of brightness.

The following script can be used to control the brightness of the red LED:

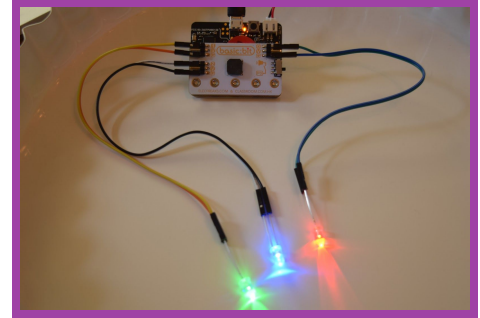
```
forever
  local percent 0
  set digital pin 0 to 
  wait 100 × percent microsecs
  set digital pin 0 to 
  wait 100 × 100 - percent microsecs
```

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This script works by turning the LED on and off very fast and changing the percent of time that the LED is on versus off. For example, when percent is equal to 1, then the LED is on for 100 microseconds and off for 9,900 microseconds. The total time is 10,000 microseconds (100 + 9,900), so the LED is on of 1% of the total time. When percent is equal to 50, the LED is on for 5,000 microseconds and off the other 5,000 microseconds.

The total time for one cycle is 10,000 microseconds, or 1 / 100th of a second, which means the LED turns on and off 100 times every second. For most people, those flashes will merge together and appear to be a steady glow whose brightness is determined by the percent of time the LED is on.

With this script running, change the value of *percent* to different numbers between 0 and 100 to see how the brightness changes. Do you see a more noticeable brightness change between 1 and 2 or between 99 and 100?



To control the brightness of all three LEDs, make two additional copies of this script and change the pin numbers. You can also add a *when started* block to each script and change the name of the "percent" variable to indicate which color LED the script controls.

```

when started
  forever
    local red 1
    set digital pin 0 to on
    wait 100 x red microseconds
    set digital pin 0 to off
    wait 100 x 100 - red microseconds

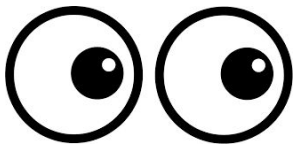
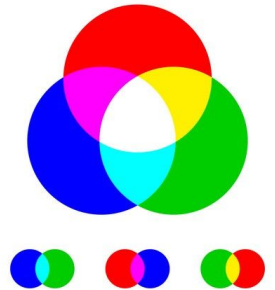
when started
  forever
    local green 20
    set digital pin 1 to on
    wait 100 x green microseconds
    set digital pin 1 to off
    wait 100 x 100 - green microseconds

when started
  forever
    local blue 80
    set digital pin 2 to on
    wait 100 x blue microseconds
    set digital pin 2 to off
    wait 100 x 100 - blue microseconds
  
```

Click the start button and edit the values of the red, green, and blue local variables to mix colors in different ways. Can you find numbers that approximate white?

Understanding Color Vision

The colors red, green, and blue -- often abbreviated RGB -- come up frequently when working with colors on computers. Each pixel in a digital image has values for red, green, and blue that determine the color of that pixel, and RGB values are used to specify precise colors when creating web pages and digital media.



What's so special about the colors red, green, and blue?
How do those three light colors make all the other colors we see?

The answer lies in the way our color vision works. Most people have three types of color receptors in their eyes, with peak color sensitivities around the colors red, green, and blue. Although each receptor is most sensitive to its peak color, it also detects a range of colors around that peak. Pure yellow light falls between the red and green peaks, so it stimulates both red and green receptors a medium amount but it does not make much impression on the blue receptors. Our brain combines the output of all three receptors and comes up with "yellow".

By mixing the right amounts of red and green light, we can stimulate the red and green color receptors the same amount that they would be stimulated by pure yellow light. Our brains thus say "yellow!", even though there is not any actual yellow light present. Digital imagery, film-based photography, and color printing all depend on this ability to use just three colors to trick our eyes into seeing all the colors of the rainbow. Most people can distinguish about 10 million different colors.

Other animals have different color vision systems. Many birds and insects can see ultraviolet light that humans cannot. Some animals have four or five different color receptors, as opposed to the three in humans and the mantis shrimp has twelve! Their world must be full of subtle color variations that human eyes cannot distinguish.

For more information, see https://en.wikipedia.org/wiki/Color_vision.