PAPER PIANO

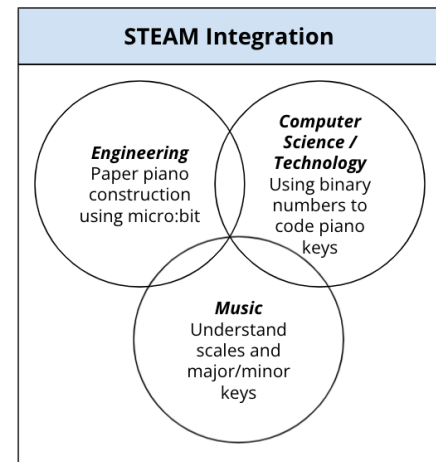## INTRODUCTION TO INTERACTIVE MICROCONTROLLER SYSTEMS USING MICRO:BIT

Lesson Overview

In this 5-E Model Project-based Learning unit students are introduced to music technology, interactive microcontroller systems and basic musical scales by constructing a paper piano and learning to use a micro:bit to control it. The project can be done with music, music technology, or introductory computer science students. It is intended for 6th – 8th grade students.

Project Length

The project is expected to last about 6 hours.

Learning Goals

STEAM Integration

Engineering
Paper piano construction using micro:bit

Computer Science / Technology
Using binary numbers to code piano keys

Music
Understand scales and major/minor keys

Computer Science Learning Goals	Arts Learning Goals
- To control the output of a device using input from a user - To determine the number of outputs possible from a given number of inputs based on binary numbers - To be introduced to simple block coding	- To explore the interrelated principles between music and computer science - To create and share melodies and rhythmic phrases using digital tools

Lesson Vocabulary

Circuit, system, microbit, wires, digital input, binary numbers, conditional statements, conductive material

Materials needed

- Per student:
  - Electronics: MicroBit board, USB cable, battery pack, 5 alligator clips
  - Piano supplies: cardstock, paper, copper tape or aluminum foil, glue stick
- A computer with access to makecode.microbit.org in their browser

Learning Standards

Georgia Computer Science Standards

- MS-CS-FCP-2.3: Demonstrate an understanding of the fundamental concepts for how computers process programming commands (hex, binary, sequence of commands, conditionals, loops)
- MS-CS-FCP-3: Utilize computational thinking to solve problems
- MS-CS-FCP-4: Design, develop, debug, and implement computer programs
    - 4.2: Utilize the design process to brainstorm, implement, test, and revise an idea
    - 4.6: Develop an event driven program
    - 4.7: Create a program that accepts user and/or sensor input and stores the result in a variable
    - 4.9: Develop a program that makes a decision based on data or user input
    - 4.10: Debug a program with an error
- MS-CS-FCP-5: Explore the relationship between computer hardware and software
    - 5.4: Create a product that analyzes how simple computer hardware can be used to develop innovative new products that interact with the physical world

Georgia Music Technology Standards

- MMSMT.6: Listening to, analyzing, and describing music
    - Uses sequencing software to isolate individual elements for critical listening
    - Uses sequencing software or digital audio workstation to compare and contrast musical styles, genres, and performances

Background for Teachers

Knowledge Integration

Teachers implementing the lesson should:
- Understand micro:bit programming and basic circuitry
- Understand binary to decimal and decimal to binary conversion
- Have a basic understanding of the C major scale (do-re-mi-fa-so-la-ti-do)

Learning Resources

Art (Piano) Background Information:
- A basic understanding of the notes on a piano will be helpful to give the students a deeper understanding of the design and code for the seven keys on the basic paper piano. If the teacher wanted to dive deeper into the lesson, they can learn about major/minor keys and how to compose basic songs on the piano.
- Basic C-Scale on a piano
- Piano Keyboard notes

Computer Science Background Information:

- There are excellent tutorials online that explain micro:bit programming and basic circuitry. The following micro:bit resources are useful for getting started with micro:bit technology in your classroom
  - Introduction
  - Tutorials for micro:bit Practice
  - Coding using micro:bit

Section Goal: Students are introduced to the concept of music technology by exploring newly designed musical instruments and discussing how musicians use coding and computer science in their music.

Section Activity (Budget 30 minutes):

- Introductory Discussion: Begin the discussion by asking about instruments students are familiar with and discuss how sound is produced in each. It is useful to project pictures of different types of traditional instruments.
  - o Do the instruments incorporate electronics, or are they strictly acoustic?
  - o What does the musician have to do to produce the sound?
  - o What are the important parts of each instrument?

- Additional Discussion questions:
  - o Have you ever thought about designing your own new instrument?
  - o What type of instrument would you design?

- Introduce the Guthman Competition

  Script: The Guthman Competition is like the Shark Tank or "X-Prize for Music" and is one of the top competitions for music technologists. The new instruments feature a mix of digital and traditional components that change how we perform and experience music. Musicians are challenged to invent the next greatest instrument using their knowledge of science, math, technology, engineering, and music. They are also challenged to think about how the instrument can solve a problem or reach new audiences.

- Show examples of instruments that people have designed as part of the Guthman Competition.
  - o Session activity: The class should watch 3-5 videos of the instruments in the Gallery of the Guthman Competition and either as a class or independently read the side panels and descriptions of the instruments. Students should vote on their favorite instrument, discussing what elements they particularly liked. Discuss how electronics and computer science are incorporated into the instruments.

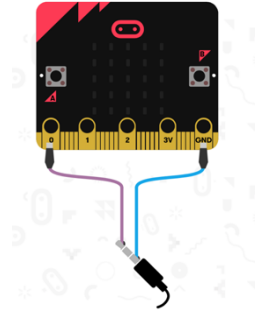   *In the next section, students will explore micro:bits.*

Section Goal: Students will explore micro:bits to understand how they can be used to generate sound.

Section Activity (Budget 60 minutes):

- Introduction to Micro:bit for music module:
    - Instruct students to www.makecode.org. This website will allow the student to code inside a web browser. On the left hand side of the screen is the '**toolbox.**' This toolbox will allow us to bring different blocks of code into our projects. The main area to the right is out '**coding area'.**
    - 'Input' and 'music' code blocks will be used for this section.

- Connection:
    - Section materials: micro:bit, USC cable, 2 alligator clips
    - Use the supplied USB cable to connect the micro:bit to the computer. If there is no USB cable available, the browser virtual micro:bit can be used to work on and follow along.

- Simple Block Coding Exercise for music/sound:
    - First, click the 'Input' tab in the toolbox and select 'On Button A pressed'. This will add a code block into the coding area. 'On Button A pressed' will execute any code inside its block when the A button is pressed.
    - Next, click the 'Music' tab and under the '**melody**' section select 'play melody ([][][][]) at tempo (120) BPM'. This will add another code block to our coding area, which will be greyed out and has a yellow line around the block. This is a notification that it needs to be placed inside a block somewhere.
    - Next, drag our 'play melody' block inside the 'On Button A pressed' block.
    - Inside the 'play melody' block, click the music note -- a note grid will appear. Click on the white buttons to add notes to a melody, or click between the 'editor' and 'gallery' button. Inside the gallery are prebuilt scales and melodies that can used in the codes.
    - Once the notes or premade melody has been selected, the code is ready to download into the micro:bit.
        - If a web browser is used, make sure to click the speaker icon to activate the audio to play. Click the 'A' button on the micro:bit to hear the melody.
        - If a physical micro:bit itself is used, make sure its connected to the computer via USB and that it is showing up next to the 'download button.'
        - Click the USB symbol and the web browser will download it directly to the micro:bit.

o   To hear the music using the physical micro:bit, the alligator clips must be connected to the piezo speaker. Connect one side alligator clip to the '0' gold tab and the other end to one of the metal tabs on the piezo speakers. Do the same for the 'GND' tab by connecting one end of the alligator clip to the 'GND' tab and the other end to the other metal tab on the piezo speaker.

▪   A pair of headphones can be used with the 3.5mm by following the image provided on the web based micro:bit.

In the next section, students will connect their understanding of binary numbers with the piano keys.

EXPLAIN #1 Understanding Binary Numbers and Coding Piano Keys

Section Goal: Students will be introduced to the concepts of binary numbers, their use in coding, and explore how piano keys can be coded using binary numbers.

Section Activity (Budget 60 minutes):

Decimal #	Binary #
1	001
2	010
3	011
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010

- Understanding Binary Numbers and Coding
  - o   Students should understand that binary numbers are a series of 0's and 1's that is used in computer programming as digital data as input and output of the system.
    - ▪   Lesson example: turning electricity on and off can be programmed using off (0) and on (1).
  - o   Decimal numbers can all be written as binary numbers.
    - ▪   Guide students through how to translate decimal numbers to binary numbers.

Piano Key	Decimal #	Binary #
C	1	001
D	2	010
E	3	011
F	4	100
G	5	101
A	6	110
B	7	111

- Extend this idea with a discussion about the total number of keys in a musical scale (7), and the idea that if each key is numbered with a decimal number, then each can also be defined by a unique binary number.
  - o   Explain the C scale on a piano
  - o   Guide the students through creating a list of the notes and their corresponding binary numbers.
  - o   Example: E is the **third** note in the C major scale – which can be converted into decimal number 3, or into binary number 011.
- Students will fill out the Binary Worksheet for each of the 7 keys. Be sure all digits, even if they are 0's, are included, as they are important in coding the piano keys.

o   Example: When expressing the decimal number "3" in binary form, make sure all three bits are used – "011"

In the next section, students will create a paper piano.

EXPLORE #2 Constructing the Paper Piano Keys

Section Goal: Students will engage in a hands-on activity to construct the paper pianos.

Section Activity (Budget 60 minutes):

- Students will construct the paper pianos (individually or as a group of up to 3 students) and have it ready to connect to the micro:bit.
- To construct the pianos, have the following resources ready:
    o   Cardstock, paper, copper tape or aluminum foil, glue stick
        ▪   Paper Piano Instructions

Note: When working in groups, be sure students in each group have a varied understanding of binary numbers and coding the piano keys, for students to support each other in fully grasping the concept.

Evaluation: Keep track of student understanding through the Binary Worksheet.

In the next section, students will add codes to the paper piano to create a working prototype.

EXPLAIN #2 Connecting the Piano to the Micro:bit and Creating the Code

Section Goal: Students will learn to code the paper piano keys using the micro:bit.

Section Activity (Budget 60 minutes):

Materials Needed: MicroBit board, USB cable, battery pack, 5 alligator clips

- Once the paper pianos have been created, students will connect the piano keys to the micro:bit.
- Refer to the last page of the Paper Piano Instructions to connect the micro:bit to the paper piano.
- First, connect an alligator clip to **Pin 0** and **GND** for our headphone/speaker output.
- Next, connect alligator clips to the copper tape.
    o   Strip 0/Line 0 will connect to **Pin 2**
    o   Strip 1/Line 1 will connect to **Pin 8** (tiny one next to Pin 1)
    o   Strip 2/Line 2 will connect to **Pin 1**
    o   Key Strip to **3V Pin**
- Once all the pins are connected to the paper piano, download the code here: Micro:bit Paper Piano Code.
    o   Click "edit code" in the top right of the screen, to the Make:Code web based coding environment. Then, click "Download" on the bottom right of the screen.

- o   Connect the micro:bit to the computer using the supplied USB cable.
- o   Once connected, there will be a USB symbol next to the "download" button. Click this button to send the code directly to the micro:bit.
- o   Test the piano keys for accuracy.
- After the students download the code, engage in discussions to examine the downloaded codes, and identify different functions.

Note: Students can identify errors in wiring the micro:bit, or in constructing the piano through testing.

In the next section, students will expand and reflect on their understanding of the lesson.

ELABORATE Musical Elaboration

Section Goal: Students will expand on the concept of coding the piano keys and constructing the pianos to alter the piano musically, and brainstorm about how micro:bits might be used to design a new instrument. Students might also create and perform a musical composition.

Section Activity (Budget 60 minutes):

- Possible activities
    - o   Students can alter the downloaded code to make the piano play to a scale or musical sequence besides C Major.
        - ▪   Example: Coding the piano key to C Minor, or E Major by using the A/B buttons on the micro:bit as toggle switches.
        - ▪   Change the order of the notes and keys
    - o   Students can join with another group to arrange a short performance to be done after the project has been completed.

In the next section, be sure to measure student understanding and completion of the activity.

EVALUATE Wrapping Up

Section Goal: The final product of the lesson will be a working piano. Students should engage in meaningful discussion and reflect on their learning.

Section Activity (Budget 30 minutes):

- Potential topics
    - o   How does the paper piano make learning music and playing the piano more accessible to everyone?
    - o   What other instruments could be designed using this process? How would you expand your paper piano to create the "next" great instrument?

- Facilitate student understanding with the following questions:
  - Why do we use binary numbers to code the piano keys, instead of individually connecting each key to an input?
  - What are some different methods of input that can be used with the micro:bit to modify the codes on the piano?
  - What are potential ways to make the piano circuits or codes more efficient?