The BBC micro:bit – A global physical computing revolution

[Extended Abstract]

ARM

BBC

Lancaster University

Micro:bit Educational Foundation

Microsoft

ABSTRACT

The micro:bit rocks!

1. INTRODUCTION

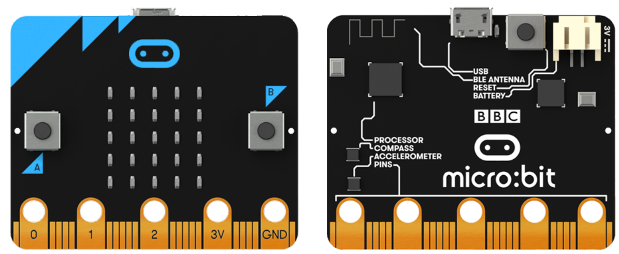
In the early 1980's, the British Broadcasting Corporation (BBC) introduced a whole generation of educators and students in the United Kingdom (UK) to computing through the *BBC Computer Literacy Project*, which featured the BBC Micro, a 6502-based personal computer designed and produced by Acorn Computers Ltd. (referred to at times as the "British Apple"). The project was very sucessful: more than 80% of UK classrooms had a BBC Micro and many of today's computing professionals from the UK first encountered computing through the BBC Micro[REF].

Fast forward to 2015: the BBC sought to again inspire a new generation get creative with coding, programming and digital technology through its *Make It Digital* initiative, as well as to support the UK's mandate to teach computer science concepts at all grade levels. [2]

As part of this effort, the BBC introduced the micro:bit (see Figure 1), a small programmable and embeddable computer designed, developed and deployed by the BBC and partners (including ARM, Microsoft and Lancaster University) to approximately 800,000 UK middle school students in 2015-2016. Harkening back to its work with the BBC Micro, the BBC described the micro:bit as its "most ambitious education initiative in 30 years, with an ambition to inspire digital creativity and develop a new generation of tech pioneers." [?]

By embracing a simplified constructionist [?] approach to computing education, the micro:bit has moved from a local educational experiment in the UK to a global phenomenon, now present in over 37 countries. Driving the worldwide expansion is the Micro:bit Educational Foundation (`www.microbit.org`), a non-profit organization established in September 2016, with the support of its founding partners. [1]

[1] ARM, Amazon, BBC, British Council, IET, Lancaster University, Microsoft, Nominet, and Samsung.



(a) (b)

Figure 1: The micro:bit: (a) front, with two buttons, 5x5 LED display, and edge connector (bottom); (b) back, with processor, accelerometer, compass, Bluetooth, USB and battery ports.

In this paper, we describe the key decisions and lessons from delivering the BBC micro:bit in the UK and then expanding to reach more educators and students around the world. We draw from two full years of full deployment of the micro:bit in the UK, as well as deployments in Europe, the Americas, and Asia. There are approximately two million micro:bits now in the market and many hardware, content, and education partners participating.

2. THE BBC MICRO:BIT

As mentioned in the Introduction, the motivation for the BBC micro:bit project stemmed from the BBC's previous history with computing education and the BBC Micro project, the desire to address the growing digital divide in the UK [?], as well as the UK government's mandate to each computer science at the K-12 grade levels.

The goals for the BBC micro:bit project were:

- B1 to provide a simple creative experience for physical computing, wearable and Internet of Things (IoT) projects;
- B2 to supply a device that can continue to provide learning opportunities as the user's expertise grows.
- B3 to give students an exciting, engaging introduction to coding;
- B4 to stimulate curiosity about how computing technologies can be utilized to solve problems that students identify.

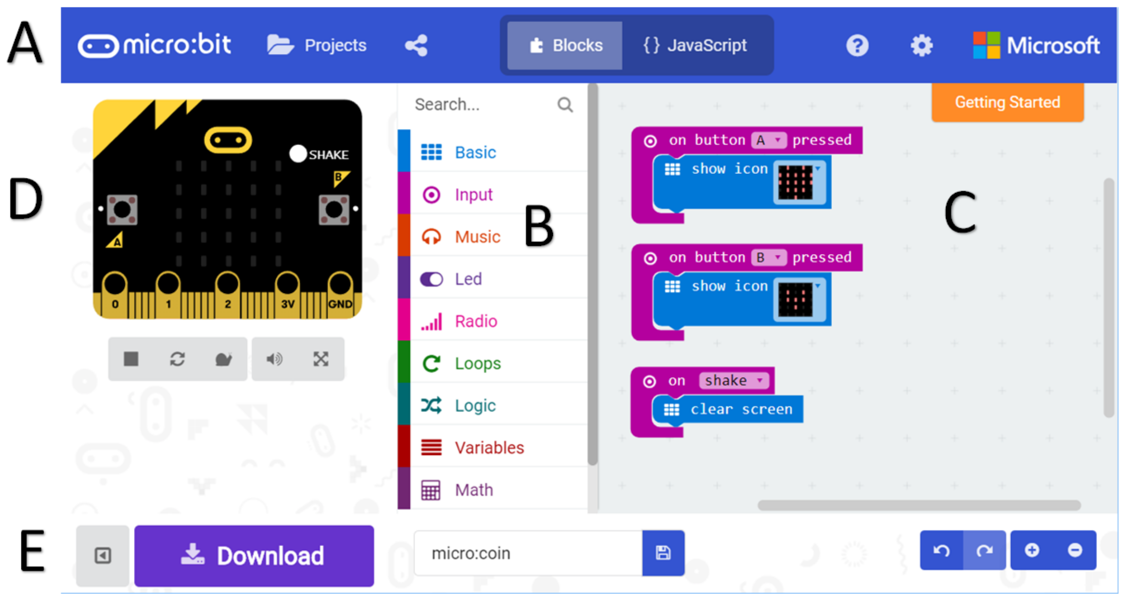


Figure 2: MakeCode web app for the micro:bit (`http://makecode.microbit.org`).

[**BBC prototype by Michael Sparks and user trials**]

In December 2014, the BBC issued an Request for Participation for "Delivery of a hands-on learning experience for the Make it Digital season", which was the micro:bit project. Twenty-nine partners were invited to contribute hardware, software, services, teaching materials, packing/distribution, logistics, events and funding. Work on the project commenced in February 2015, with delivery of a web site/app in September 2015 (which was critical for training teachers) and delivery of the micro:bits in the second half of the 2015-2016 school year.

2.1 Why physical computing?

Really need Howard Baker's input on this.

- broad reach
- topical

2.2 The hardware

Figure 1 shows (a) the front and (b) the back of the micro:bit, which measures 4cm x 5cm. The aesthetic of the micro:bit is designed to be engaging from the off, with streaks of hair (upper left) and a friendly face (upper middle). The micro:bit board hosts a variety of sensors (temperature, accelerometer, magnetometer, light level), a 5x5 LED matrix, two user-defined buttons, as well as Bluetooth Low Energy (BLE) communications.[2]. More importantly, the device embraces these sensors in its design bringing them to the fore, so to expose its users to the future: a world of embedded, Internet enabled devices.

In contrast to the Uno which has no built-in sensors, the micro:bit allows many projects to be completed with no additional hardware or wiring. The holes on micro:bit's edge connector allows additional external sensors and actuators to be connected via crocodile clips or banana plugs. The micro:bit's BLE capabilities introduces networking to the picture, and enables streaming of data and command/control operations among the micro:bit, smartphones, laptops, as well as other micro:bits. As with Arduino, an ecosystem of micro:bit shields (hardware peripherals) that accommodate the micro:bit's edge connector expands its capabilities (`http://microbit.org/resellers/`).

The micro:bit can be programmed over USB via a host computer (usually a laptop or desktop) and then embedded in projects where it runs on battery power.

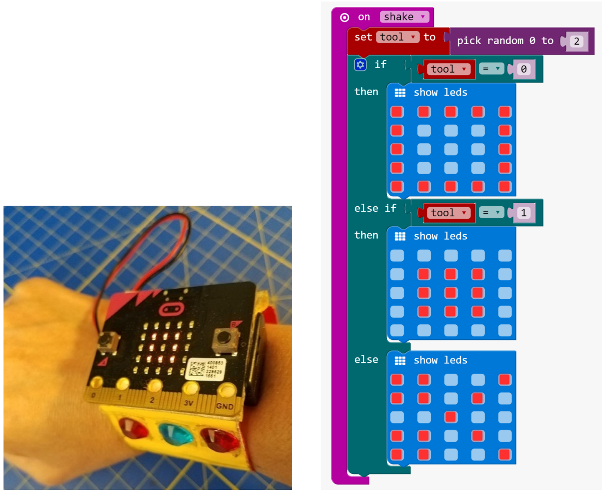
The unique combination of features supplied by the micro:bit enables a creative, extensive experience for physical computing (B1, B2).

2.3 The software

The design of the micro:bit coding tools also was oriented towards a simple starting experience with room for progression (B3, B4). Based on in-school trials with a micro:bit prototype, the BBC focused on delivering a web app based on the popular Blockly framework [1] to permit students to create scripts via drag-and-drop operations in a web browser, and see the execution of their scripts via a simulator; text-based coding via scripting languages also was identified as an important feature. As the micro:bit would be incorporated into standalone projects, it also was essential for the user's program to be stored on the device for future untethered execution via battery power.

The solution delivered by the BBC's partners evolved from the initial design to include support for Blockly, JavaScript and Python, all via web apps. Figure 2 shows a screen snapshot of the MakeCode web app for the micro:bit, which supports programming via both Blocky and JavaScript. The web app has five main sections: (A) menu bar with access to projects and examples, and switching between Blockly and JavaScript editors; (B) Blockly toolbox of micro:bit API

[2]The micro:bit has a whopping 16kB of RAM and 256kB of Flash memory, compared to the Uno's 2kB of RAM and 32kB of Flash



(a) (b)

Figure 3: Micro:bit watch for playing rock/paper/scissors.

categories; (C) Blockly programming canvas with a simple reactive program; (D) micro:bit simulator for execution of the user's program in browser; (E) download button, which invokes the in-browser compiler/linker to produce a binary executable.

The Python solution for the micro:bit is based on MicroPython (`http://micropython.org`) an implementation of Python 3.0 for microcontrollers. It includes a full Python compiler and runtime that runs on the micro:bit and supports a read-eval-print loop (REPL) to execute commands sent via a terminal, as well as to import and run scripts from the Python web app for the micro:bit (`http://python.microbit.org`).

3. PROJECTS

In this section we present a sampling of projects that illustrate the capabilities of the micro:bit.

3.1 Wear and Play

Figure 3 shows one of the most popular micro:bit projects: a watch that plays the rock/paper/scissors game when shaken; the program reacts to a shake event by choosing a random integer between 0 and 2 and displaying a rock, paper or scissor shape on the LED display, based on the number chosen. The user can use this simple app to play the game with themselves or a a friend. The project consists of a making step and coding step, as shown at

`makecode.microbit.org/projects/rock-paper-scissors`

Many micro:bit projects use simple classroom supplies. The reaction game project (Figure 4) uses cardboard, aluminum foil, and crocodile clip connectors to illustrate the use of circuits with a game that measure reaction time. Crocodile clips connected to pins P0, P1, P2 and GND also are connected to aluminum pads. The user completes a circuit by touching the GND pad and one of other pads. The pad labelled "START" begins the game; after a 1-3 seconds (randomly determined), the micro:bit display lights up - the first user to touch their pad wins, and their reaction time is displayed:

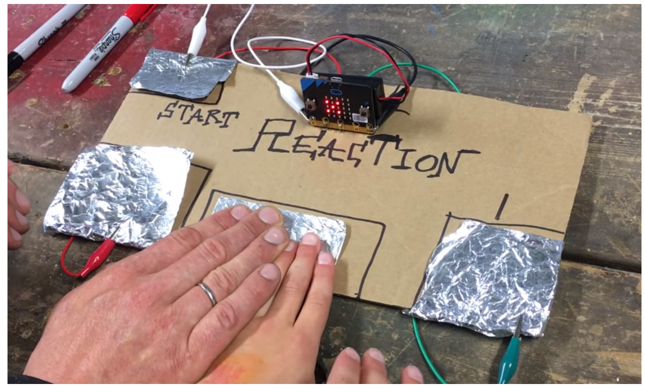


Figure 4: Reaction game.

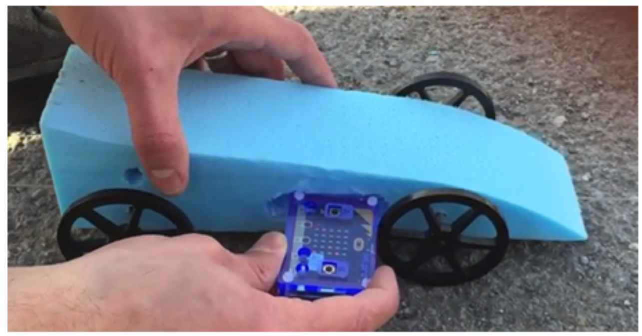


Figure 5: Bloodhound Model Rocket Car with embedded micro:bit for measuring acceleration.

`makecode.microbit.org/projects/reaction-time`

3.2 Measure

The micro:bit's built-in sensors and small size make it perfect for embedding in science and technology projects. The Bloodhound Model Rocket Car is part of the Bloodhound Project, [3] whose goal is to set a new world land speed record and inspire students about STEM subjects. Students design, build and race model rocket cars in competition, learning about physics, aerodynamics, and mechanical engineering. Microsoft worked with the Bloodhound Project to incorporate a micro:bit into the car's design, as shown in Figure 5; the micro:bit captures the (X,Y,Z) accelerometer data of the rocket car during its race. After the race, students can upload the data from the micro:bit and analyze the performance of their cars.

Figure 6 shows an environmental project that uses the micro:bit to measure soil moisture. The combination of water and soil nutrients makes the soil have some conductivity. The more water there is in the soil, the greater its conductivity, which can be measured using the analog pin API. In this project, the student first learns to calibrate the measurement readings using dry and wet soil samples. Then, the micro:bit is coded to periodically record the reading. Using the micro:bit's Bluetooth radio, the readings also can be sent to a central source. In this way, the moisture of a set of soil samples (in a classroom) can be recorded and reported. For more about this project, see:

[3] `www.bloodhoundssc.com`

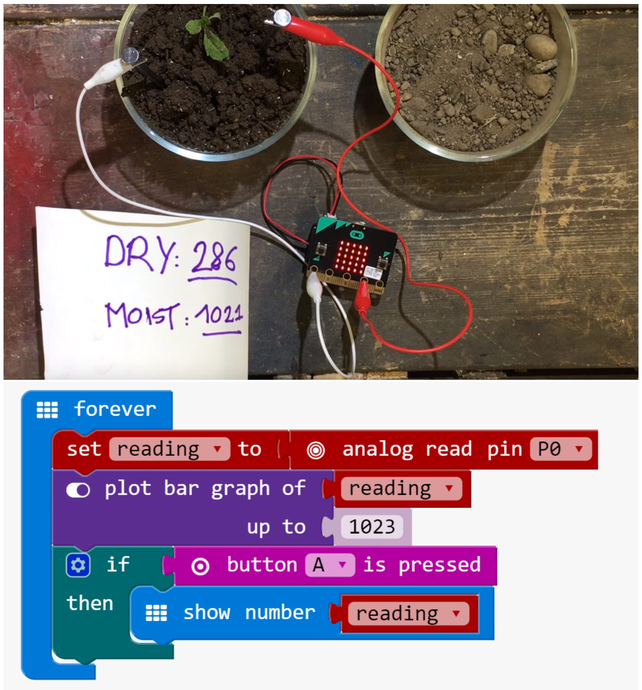


Figure 6: Measuring soil moisture via micro:bit pins.

`makecode.microbit.org/projects/soil-moisture`

3.3 Network

Using a lower level of the Bluetooth stack, the micro:bit supports a simple radio broadcast protocol that can be used to send short messages to a set of micro:bits. Figure 7 presents a simple example in JavaScript that shows how to use a micro:bit to communicate your "mood" to other micro:bits in the vicinity. Note that the micro:bit that sends a message does not receive that message.

The following two projects use the micro:bit radio to illustrate how fireflies synchronize their blinking and how infections spread:

`makecode.microbit.org/projects/fireflies`

`makecode.microbit.org/projects/infection`

3.4 Control

The micro:bit can be attached to external actuators, such as servos, to create systems that respond physically to their environment.

4. THE MICRO:BIT EDUCATIONAL FOUNDATION

The Foundation's Mission Statement is to:

- enable and inspire all children to participate in the digital world, with particular focus on girls and those from disadvantaged groups.

- make micro:bit the easiest and most effective learning tool for digital skills and creativity.

```
input.onButtonPressed(Button.A, () => {
  radio.sendString("H");
});

input.onButtonPressed(Button.B, () => {
  radio.sendString("S");
});

radio.onDataReceived(() => {
  let data = radio.receiveString();
  if (data == "H") {
    basic.showIcon(IconNames.Happy)
  } else if (data == "S") {
    basic.showIcon(IconNames.Sad)
  } else {
    basic.showString("?");
  }
});
```

Figure 7: . Broadcasting simple messages using the micro:bit radio.

- work in collaboration with educators to create and curate exceptional curriculum materials, training programmes and resources.

- build and support communities of educators and partners to remove the barriers to learning digital skills

asdasd stuff is needed at the end of an itemize?

4.1 The future of the micro:bit

4.2 Inspirational Stories

5. CONCLUSION

6. ACKNOWLEDGMENTS

7. REFERENCES

[1] N. Fraser. Ten things we've learned from blockly. In *Proceedings of the 2015 IEEE Blocks and Beyond Workshop (Blocks and Beyond)*, BLOCKS AND BEYOND '15, pages 49–50, 2015.

[2] S. Peyton Jones. Computer science as a school subject. In *Proceedings of the 18th ACM SIGPLAN International Conference on Functional Programming*, ICFP '13, pages 159–160. ACM, 2013.