The BBC micro:bit - from the UK to the World

[Extended Abstract]

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ABSTRACT

The micro:bit rocks!

1. INTRODUCTION

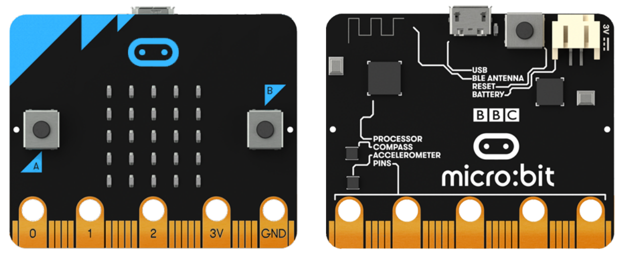
The micro:bit is a small programmable and embeddable computer designed, developed and deployed by the BBC and partners (including ARM, Microsoft and Lancaster University) to approximately 800,000 UK middle school students in 2015-2016. Part of the BBC's Make it Digital Campaign, the BBC described the 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." [**?**]

Figure 1 shows (a) the front and (b) the back of the micro:bit, which measures 4cm x 5cm. Like the Arduino Uno, the micro:bit is a single-board microcontroller that can be programmed via a host computer (usually a laptop or desktop) and then embedded in projects where it runs on battery power. In contrast to the Uno, which has no built-in sensors, 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.[1].

The design of the micro:bit hardware was driven by the first two objectives of the BBC micro:bit project: (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.

On the hardware side, the micro:bit's built-in sensors, buttons and LED display allow 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. 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 ecosytem of

[1]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 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.

micro:bit shields (that accommodate the micro:bit's edge connector) expand its capabilities greatly.[2]

The design of the micro:bit coding tools also was oriented towards a simple starting experience with room for progression. In particular, the coding objectives of the project were: (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.

Based on user trials with a micro:bit prototype at Years 5 and 7 (3rd and 5th grade in the US, respectively), the BBC focused on delivering a web app based on the popular Blockly framework [1] to permit Year 7 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 also was identified as an important feature. As the micro:bit would be incorporated into standalone projects, it was essential for the user's program to be compiled and installed in non-volatile storage on the micro:bit where it could be run via battery power.

The solution delivered by the BBC's partners evolved from the initial design to include:

- support for Blockly, JavaScript, Python and C++;
- an efficient C++ runtime for the micro:bit created by Lancaster University;
- a web app (`http://makecode.microbit.org`) with Blockly and JavaScript editors, micro:bit simulator, and a com-

[2] `http://microbit.org/assets/documents/AccessoryGuideSummer18.pdf`

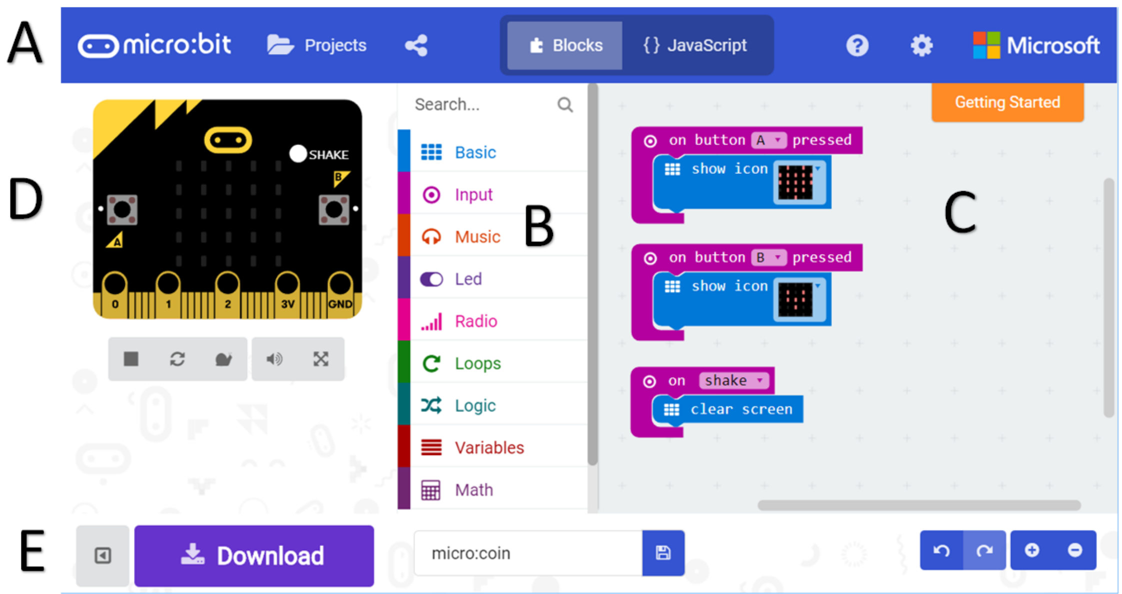


Figure 2: MakeCode web app for the micro:bit

piler to machine code, linked against a pre-compiled C++ runtime;

- an on-device compiler and read-eval-print loop (REPL) for Python (via `https://micropython.org/`, an implementation of Python for microcontrollers);
- ARM's DAPlink firmware makes the micro:bit appear as USB pen drive on most operating systems, enabling a simple file copy operation to install a user's program on the micro:bit (no device drivers needed).

MakeCode, MicroPython, and the C++ runtime are all open source.[3]

Figure 2 shows a screen snapshot of the MakeCode web app for the micro:bit.

What happened in terms of deployment and experience:

- first full school year was 2016-2017, during which micro:bit Education Foundation got started;
- two full school years complete with experience in more countries
- approximately two million micro:bits in market;
- lots of partners participating (ICSTE and CSTA 2018)!!

2. CONTEXT: PHYSICAL COMPUTING

As discussed in the Introduction, the micro:bit is a device with similarities to the Arduino family of printed circuit boards. Such devices as known by the term *physical computing*, as they are designed to be placed in and interact with our physical environment (as opposed to computer programs whose main manifestation is realized on a monitor, like games). Physical computing lives in the spaces between computing and many other disciplines: art, industrial design, health, environmental monitoring; it has close ties to cyber-physical systems, embedded systems, and IoT.

Physical computing benefits:

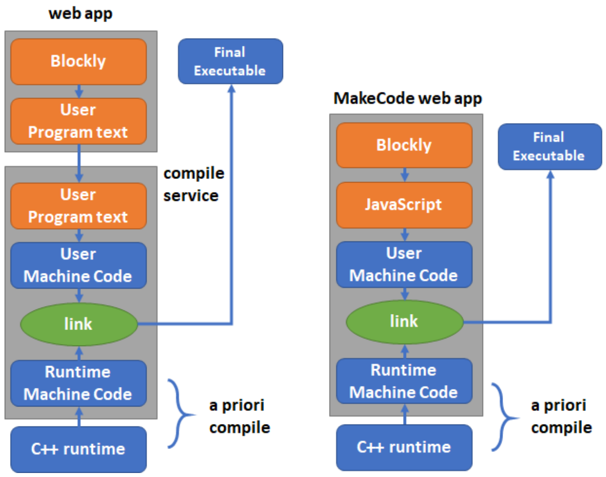
- broad reach because of diverse applications of physical computing – leverage fine arts, music, design, etc. in projects;
- increased motivation and connections because of tangible visible outcome (rather than virtual on screen);
- learning by doing: many ways to achieve goal (no single correct solution)
- natural division of labor for more complex projects (design, hardware, software, ...)
- full system view of computing: hardware and software working together.

2.1 Wiring and Arduino

To help explain the BBC micro:bit, it's very instructive to understand Hernando Barragan's 2003 Master's thesis, "Wiring: Prototyping Physical Interaction Design", the inspiration for the Arduino system [?]. His objective was to make it easier for non-technical creators, such as artists and designers, to leverage electronics in their their work by simplifying the hardware and programming experience. In particular, he said of existing work: "Current prototyping tools for electronics and programming are mostly targeted to engineering, robotics and technical audiences." Of Wiring's design, he identified the following key concepts:

- a simple cross-platform integrated development environment (IDE) to create so-called "sketches";
- simplified application programming interfaces (APIs) to access a microcontroller's resources;

[3] At `https://github.com/microsoft/pxt`, `https://github.com/micropython/micropython`, and `https://github.com/lancaster-university/microbit-dal`, respectively.



(a) (b)

Figure 3: Web and compiler designs: (a) initial BBC design; (b) final design, as implemented in MakeCode.

- leverage open source compiler/linker toolchain, transparent to the end user;
- a bootloader to make it easy to upload a compiled sketch to the microcontroller;

Also key to Wiring was openness of both the hardware and software comprising the system.

But, still some issues:

- reliance on the C language and C compiler (needs to be installed)
- very poor experience in IDE
- USB bootloader requires device drivers on some systems

2.2 The BBC micro:bit

BBC micro:bit inherits the raw PCB nature of Arduino (everything is visible to the end user).

First key idea of the BBC micro:bit: NO WIRING REQUIRED! Second key idea: smaller. Third key idea: web app for programming and simulating.

As shown in Figure 3(a), in the BBC design the text of a user's program (whether derived from Blockly or produced directly by the user) is submitted to a compile service that returns a final executable to be copied onto a micro:bit (connected to the host computer by USB) via a specialized loader application.

avoiding the need for a compile service for user code (as shown in Figure 3(b));

3. ACKNOWLEDGMENTS

4. 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.