Teach Computing

Teacher Guide

Physical computing kits

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National Centre for Computing Education

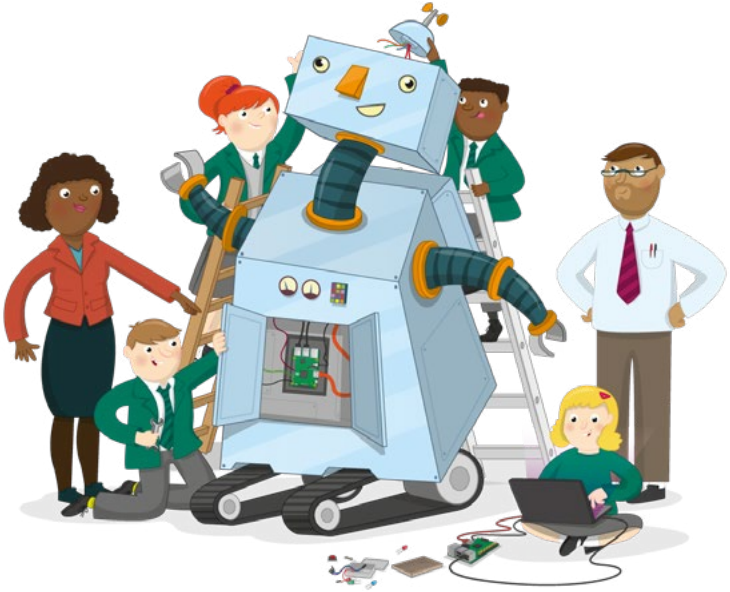
Raspberry Pi

Contents

Why physical computing?

Current research suggests that physical computing will play an important role in modern pedagogical approaches, both as a tool to engage learners and as a strategy to develop learner understanding in more creative ways. This approach also has the benefit of supporting and engaging a diverse range of learners in tangible and challenging tasks. There is also some evidence that girls engage more with physical computing, as a physical project has more immediate real world applications.

However, physical computing presents a challenge for schools and educators – both the financial cost and challenges around kit and classroom management. This is in addition to knowing how best to teach with and make effective use of such resources. The National Centre for Computing Education has developed a core Hub kit that can be loaned to schools. This guide has been developed to accompany the kit, and direct teachers to suitable resources.



What will physical computing help me teach?

Physical computing can be utilised to fulfil many areas of the computing curriculum at all key stages. Whilst primarily supporting the development of programming skills, it can also support more conceptual areas of the curriculum.

Through physical computing, learners can encounter, develop, and practice the whole range of programming skills and concepts, including sequences, loops, conditionals, functions, and data structures. Alongside applying these concepts, they will also encounter other languages, models of programming, and novel computer systems.

Physical computing projects can connect with all areas of computing curriculum, but commonly they will overlap with areas such as:

- **Computer systems** Each physical computing device is an example of a computing system with inputs, process, and outputs. Some offer storage, sensors or additional connectivity. Learning with these devices provides many opportunities for discussions and comparisons.

- **Data and information** Physical projects frequently involve some form of sensing as well as physical output, which provide great opportunities to discuss how the computers are capturing, representing, storing, and outputting that data.

- **Computer networks** Some devices offer additional connectivity, whether that be through GPIO (General-Purpose Input/Output), Ethernet, Bluetooth, or WiFi. Regardless of the means of transmission, having a class set of devices allows learners to explore how data is transmitted, the practical challenges, and possible solutions.

- **Impacts of technology** Physical computing is an area where we see direct interaction between humans and technology, where we can find and discuss many practical impacts of technology on people’s lives. How can technology assist individuals and what are some of the risks?

- **Design and development** Physical computing provides great opportunities for project-based learning, with scope to develop students skills in analysis, design, implementation testing, and evaluation. They are a great space in which students can select and apply what they have previously learnt, creating something new and/or solving a practical problem with computing.

What is in a physical computing kit?

The Hubs within the National Centre for Computing Education network have these packaged kits available for loan by schools in their region:

Crumble tray	Micro:bit tray	Raspberry Pi Pico tray	Raspberry Pi computer tray
17 Crumble controllers 34 sparkle LEDs 17 switches 17 light sensors 17 buzzers 17 micro USB cables 17 battery packs for 3 x AA batteries 34 wheels and motors 204 croc clip wires	17 micro:bits 17 battery packs for 2 x AAA batteries 17 USB cables 36 croc clip wires	10 Raspberry Pi Picos with 2 x 20 pin 0.1” headers pre-soldered 10 micro USB cables 10 ultrasonic sensors 20 wheels and DC motors 10 H Bridge boards 10 x 2 line tracking optical sensors 10 battery packs for 6 x AA batteries 10 breadboards 40 LEDS 20 croc clip wires Jumper wires (140 x M–F, 100 x M–M) 10 resistors (50 ohms) 10 buttons	10 Raspberry Pi 3B+ 10 Raspberry Pi 3B+ power supplies 10 Sense HATs 12 SD cards 21 LEDs, mixed colour 10 Breadboards 10 resistors (330ohms) 50 buttons Jumper wires (20 x F–F, 60 x M–F)

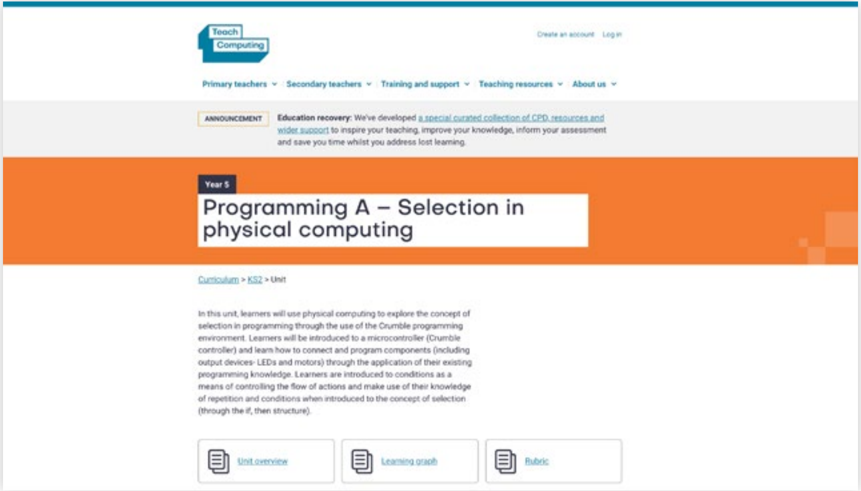
Individual trays of the core kit can be loaned by contacting your nearest NCCE Hub.

Progression

The core kit contains hardware which can be used with all key stages. In this guide, you'll find lesson plans and activities for the following:

	Key Stage 2	Key Stage 3	Key Stage 4
Crumble	✓		
Micro:bit	✓	✓	
Raspberry Pi computer		✓	✓
Raspberry Pi Pico			✓

Physical computing lessons within the Teach Computing Curriculum



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Programming A – Selection in physical computing

Curriculum > KS2 > Unit

In this unit, learners will use physical computing to explore the concept of selection in programming through the use of the Crumble programming environment. Learners will be introduced to a microcontroller (Crumble controller) and learn how to connect and program components (including output devices- LEDs and motors) through the application of their existing programming knowledge. Learners are introduced to conditions as a means of controlling the flow of actions and make use of their knowledge of repetition and conditions when introduced to the concept of selection (through the if, then structure).

The Teach Computing Curriculum acknowledges that physical computing plays an important role in modern pedagogical approaches in Computing, both as tools to engage learners and a strategy to develop learners' understanding in more creative ways. Therefore it has been included as an approach for teaching computing in the following units:

- **Year 5** Selection in physical computing
- **Year 6** Sensing, which uses a micro:bit
- **Year 9** Physical computing
- **KS4** Physical computing project

Getting started with Crumble

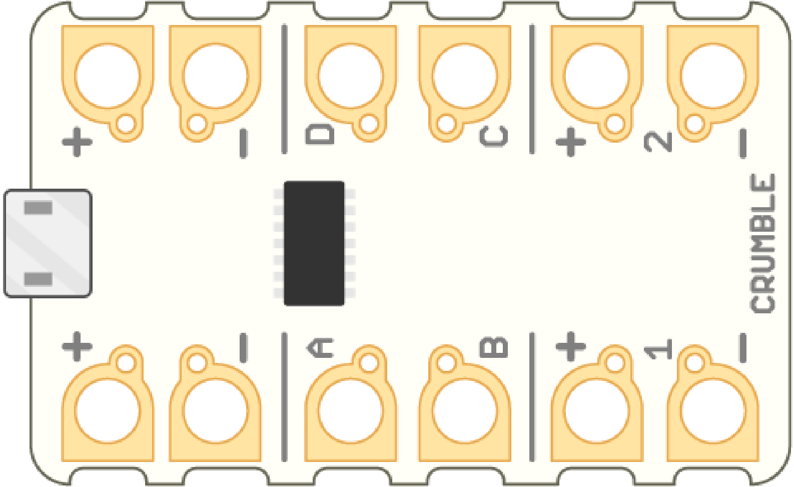
The Crumble is an easy-to-use programmable controller that is capable of driving two motors. Equipped with 4 IO (input/output) terminals, the Crumble device enables users to connect LEDs, switches, and more. The Crumble software runs on PCs, Macs, and Raspberry Pis or other Linux-based computers. It offers a block-based programming environment with blocks of code ‘snapping’ together. Programs are sent to the device via the supplied USB lead.

What do you need?

- Crumble tray from the NCCE Hub kit
- 3 x AA batteries per device if you need to use the battery box

Extra equipment you may need to deliver the activities are:

- Headphones or speakers for sound
- Craft materials such as: cardboard, rubber bands, scissors, tin foil and glue



Getting started with Crumble (cont.)

Preparations for programming Crumble

- Getting started with Crumble

Safety

- Always ensure care is taken when connecting croc leads to terminals
- Be mindful to place batteries in the battery pack correctly

Teach Computing Curriculum lessons

- Year 5 - Programming A – Selection in physical computing

In this unit, learners use physical computing to explore the concept of selection in programming through the use of the Crumble programming environment. Learners are introduced to a microcontroller (Crumble controller) and learn how to connect and program components (including output devices — LEDs and motors) through the application of their existing programming knowledge. Learners are introduced to conditions as a means of controlling the flow of actions, and explore how these can be used in algorithms and programs through the use of an input device (push switch). Learners use their knowledge of repetition and conditions when introduced to the concept of selection (through the 'if... then...' structure) and write algorithms and programs that utilise this concept. To conclude the unit, learners design and make a working model of a fairground carousel that will incorporate their understanding of how the microcontroller and its components are connected, and how selection can be used to control the operation of the model. Throughout the unit, pupils apply the stages of programming design.

This unit is also available as video lessons on Oak National Academy.

Additional resources

- Getting started with Crumble
- Crumble motor buggy
- Crumble Sparkle creature

Training

- Physical computing in primary schools – coming soon

Find out more

Visit Redfern Electronics for more information about Crumble.

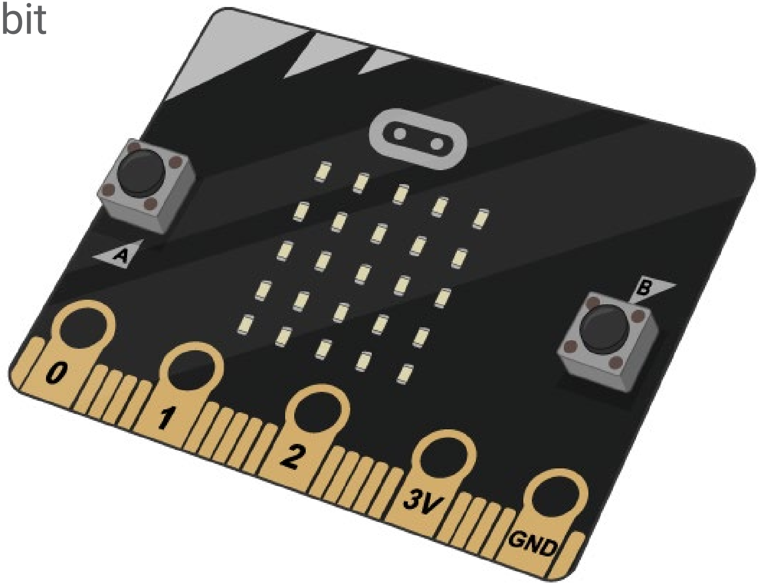
Getting started with micro:bit

The micro:bit is a microcontroller device that you can use in digital making projects. It has two buttons, 25 red LEDs in a 5 × 5 grid, and sensors for detecting movement and light, and for measuring temperature. You can also attach other input and output components to it, for example buttons, coloured LEDs, and speakers. The micro:bit is suitable for use with students at key stage 2 and key stage 3.

To program the micro:bit, you need to connect it to a laptop or desktop computer via a micro USB cable. The micro:bit is powered through this same USB cable; to make your micro:bit project portable, you can also power it using a battery pack.

What do you need?

- The micro:bit tray from the NCCE Hub kit
- AAA Batteries x 2 per device if you need to use the battery pack



Getting started with micro:bit (cont.)

Preparations for programming micro:bit

- Getting started with micro:bit

Teach Computing Curriculum Lessons

- Year 6 – Programming B – Sensing

This unit is the final KS2 programming unit in the curriculum and brings together elements of the four programming constructs: sequencing from Year 3, repetition from Year 4, selection from Year 5 and variables, introduced in Year 6 – Programming A. It offers learners the opportunity to use all of these constructs in a different, but familiar environment whilst also utilising a physical device – the micro:bit. The unit begins with a simple program which learners build and test in the programming environment before transferring it to their micro:bit. Learners then take on three new projects in lessons 2, 3 and 4, with each lesson adding more depth.

- Year 9 – Physical computing

This unit introduces learners to how data can be represented and processed in sequences, such as lists and strings. The lessons cover a spectrum of operations on sequences of data, that range from accessing an individual element to manipulating the entire sequence. Great care has been taken so that the selection of problems used in the programming tasks are realistic and engaging: learners will process solar system planets, book texts, capital cities, leaked passwords, word dictionaries, ECG data, and more. A range of pedagogical tools are employed throughout the unit, with the most prominent being pair programming, live coding, and worked examples. The Year 7 and 8 Programming units are prerequisites for this unit. It is assumed that learners are already able to write Python programs that display messages, receive keyboard input, use simple arithmetic expressions, and control the flow of program execution through selection and iteration structures.

These units are also available as video lessons on Oak National Academy:

- Year 6 – Video lesson – Sensing
- Year 9 – Video lesson – Physical computing programming

Additional resources

- Reaction game with micro:bit
- Fortune teller with micro:bit
- Against the clock with micro:bit

Training

- Physical computing in primary schools – coming soon
- Programming pedagogy in secondary schools
- Programming pedagogy in primary schools

Find out more

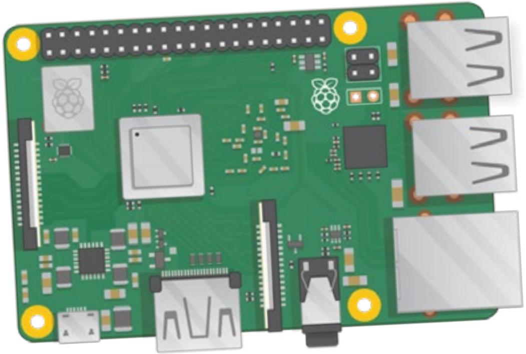
Visit the Micro:bit Educational Foundation for information.

Getting started with Raspberry Pi

A Raspberry Pi is a single-board computer that can be used for everyday tasks and for learning how to code. Thanks to its size, processing power, and General-Purpose Input/Output (GPIO) pins, it can be used in physical computing projects and as a general-purpose computer. Included in the Hub kit are the third-generation model of the computer, Raspberry Pi 3 Model B+, and a Sense HAT.

Raspberry Pi 3 Model B+

- 1.4GHz 64-bit quad-core processor
- Dual-band wireless LAN
- Bluetooth 4.2/BLE
- Faster Ethernet
- Power-over-Ethernet support (with separate PoE HAT)



Sense HAT

The Sense HAT is an add-on board for Raspberry Pi, made especially for the Astro Pi mission – it launched to the International Space Station in December 2015 and is now widely available.

The Sense HAT has an 8 × 8 RGB LED matrix, a five-button joystick and includes the following sensors:

- Gyroscope
- Accelerometer
- Magnetometer
- Temperature
- Barometric pressure
- Humidity

There is also a Python library provided.

Note: Raspberry Pi Zero and Raspberry Pi Zero W are smaller and require less power, so they're useful for portable projects, such as robots. It's generally easier to start a project with Raspberry Pi 3, and to move to Raspberry Pi Zero when you have a working prototype that the smaller Raspberry Pi would be useful for. Raspberry Pi 4 is the newest, fastest, model coming in 1GB, 2GB, and 4GB models.

Getting started with Raspberry Pi (cont.)

What do you need?

- Raspberry Pi computer tray from the NCCE Hub kit
- Monitors
- Keyboards
- Mice
- Cables to connect Raspberry Pi computers to monitors

Extra equipment you may need to deliver the activities are:

- Headphones or speakers for sound
- Network connect via Ethernet, WiFi or Bluetooth
- Craft materials such as: cardboard, rubber bands, scissors, tin foil and glue
- USB memory stick to back up students' work
- The SD Card provided comes with the operating system, Raspbian, pre-installed. From time to time you may need to format the cards and reinstall the software. Check with the Hub that you have loaned the kit from if you have any questions about this.

Preparations for programming Raspberry Pi

- Setting up your Raspberry Pi
- Using your Raspberry Pi
- Getting started with the Sense HAT

Additional resources

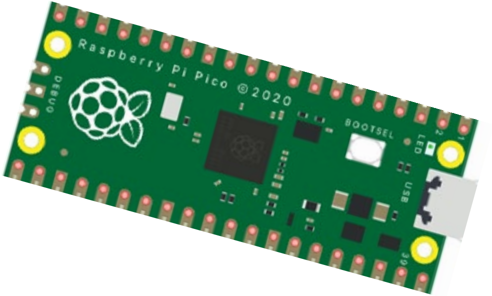
- Build a music box
- Python quick reaction game
- Node-red LED
- Compass maze
- Rainbow predictor

Training

- Getting Started with your Raspberry Pi
- Teaching physical computing with Raspberry Pi and Python
- Robotics with Raspberry Pi: Build and program your first robot buggy

Visit the Raspberry Pi Foundation for more information.

Getting started with Raspberry Pi Pico



Raspberry Pi Pico is a low-cost microcontroller device. Microcontrollers are tiny computers, but they tend to lack large volume storage and peripheral devices that you can plug in (for example, keyboards or monitors). Raspberry Pi Pico has GPIO pins, which means it can be used to control and receive input from a variety of electronic devices. It is suitable for use with key stage 3 and 4 students who have experience of writing text-based code.

What do you need?

- Raspberry Pi Pico tray from the NCCE Hub kit
- Computers running the Thonny IDE (one per pair of learners)
- 6 x AA batteries per Raspberry Pi Pico
- 1 powerbank
- 1 mini cross-head screwdriver

Preparations for programming Raspberry Pi Pico

- Getting started with Raspberry Pi Pico
  - □ Connect Raspberry Pi Pico to a computer
  - □ Install or update Thonny IDE
- A copy of the latest micropython UF2 file for learners to access

Teach Computing Curriculum lessons

- KS4 – Physical computing project

This unit introduces learners to physical computing through six lessons culminating in a finished working robotic buggy. Using the Raspberry Pi Pico microcontroller, learners will explore inputs and outputs utilising a range of hardware components including motors, reflective optical sensors, LEDs, and an ultrasonic sensor. This unit of work allows learners to practically experience the use of embedded systems in support of the GCSE computer science specifications.

Additional resources

- Blink the built-in LED of Raspberry Pi Pico

Find out more

Visit the Raspberry Pi Foundation for more information.

Where can you purchase your own physical computing equipment?

The table below lists some suppliers for the equipment found in the NCCE physical computing kits.

Tray and equipment	Suppliers
Crumble ■ Crumble controllers ■ Sparkle LEDs ■ Switches ■ Light sensors ■ Buzzers ■ Micro USB cables ■ Battery packs for 3 × AA batteries ■ Wheels and motors ■ Croc clip wires	Redfern Electronics
micro:bit ■ Micro:bits ■ Battery packs for 2 × AAA batteries ■ Micro USB cables ■ Croc clip wires	micro:bit Foundation Redfern Electronics

Tray and equipment	Suppliers
Raspberry Pi Pico ■ Raspberry Pi Picos with 2 × 20 pin 0.1” headers pre-soldered ■ Micro USB cables ■ Ultrasonic sensors ■ Wheels and DC motors ■ H Bridge boards ■ Line tracking optical sensors ■ Battery packs for 6 × AA batteries ■ Breadboards ■ LEDs ■ Croc clip wires ■ Jumper wires (M-F, M-M) ■ Resistors (56 ohms) ■ Buttons	Raspberry Pi Kitronik PiHut Farnell UK Redfern Electronics Amazon

Where can you purchase your own physical computing equipment? (cont.)

Tray and equipment	Suppliers
Raspberry Pi ■ Raspberry Pi 3B+ ■ Raspberry Pi 3B+ power supplies ■ Sense HATs ■ SD cards ■ LEDs, mixed colours ■ Breadboards ■ Resistors (330 ohms) ■ Buttons ■ Jumper wires (F-F, M-F)	Raspberry Pi Farnell UK PiHut Kitronik