Bits and Bytes

The Digital Advantage

Trainer's Notes

Background

Our world is being digitised at an ever increasing rate. Pupils will be familiar with the term but what does 'going digital' mean? In essence, digital representations of everything we can see, hear, speak, touch (and even now smell) are being developed and refined. We use its results every time we make a phone call, send e-mail, listen to music, watch TV or take a selfie. Our analogue world is being captured in discrete patterns of bits. Although many primary aged pupils may have come across the notion of bits or binary, it is important to set any secondary school work in the context of understanding that our world is increasingly digitised. There are many advantages of dealing with digital data. Bit patterns are easier to store and reliably transmit. Binary is an abstraction from the particular storage / transmission technologies. It is 'the difference that makes the difference'. Discrete, two state representations of data can be stored and transmitted across imperfect media.

The presentation introduces bits as a metaphor for switches which transmit data. The emphasis is on looking at ways to introduce some basic ideas about binary manipulation and get across the idea that the same bit pattern can be interpreted in different ways. Bitmap images provide fertile ground for exploring these ideas and link well to hexadecimal/binary conversion. Most children are familiar with the notion of pixels making up a bitmap image. The session explains how an analogue picture is digitised. It explores different ways to store and render that data. Most importantly, once children appreciate that digital images are simply an array of numbers they can begin to manipulate these numbers to change images. Activities such as these provide computational thinking challenges, and the immediacy of the visual output can be both illuminating and highly motivating.

Interpreting a bit pattern as a character rather than a pixel value introduces the notion of character coding schemes. Text encoding is an easier context in which to explore compression algorithms. That the same bit pattern can be interpreted in different ways can also lead to considerations of whether we can write a picture or display a sound. Ultimately, we want children to appreciate how our world is increasingly 'in bits' and have a sense of how easy it is to manipulate those bits with just a basic grasp of simple algorithms and linear data structures.

The aim of the day

There is a lot of ground to cover in the course of this session, building up to a major practical activity through which we hope to make the link between the digital images children increasingly take for granted and the high level applications they may usually use to manipulate them, such as Photoshop. The role of code in application software is brought to the fore with exercises to code graphic effects in Python.

The session starts by looking at activities and exercises to establish a basic understanding of the concepts. Having established the basics of numeric representation the main focus is on exploring the principles behind digital images, their capture, storage and rendering. This is rich territory with potential practical activities that link with other areas in Computing and provide opportunities to marvel at some of the technological developments and highlight the role of lesser known techniques such as Bresenham's and demosaicing algorithms.

Character coding schemes provide an opportunity to consider effective ways to encode the alphabet and explore the basic principles of compression, contrasting the dictionary approach behind Huffman encoding and Lempel – Ziv compression techniques. Finally, a practical exploration allows us to demonstrate how ascii characters in a text file can be rendered as a picture. This also introduces the idea of different file formats and the importance of file header information.

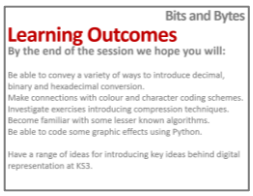
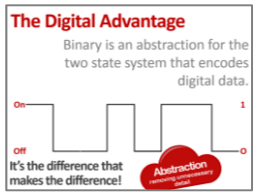
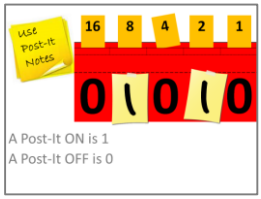
This unit aims to provide experienced teachers with ideas and activities on which to base cpd sessions for less experienced colleagues. As such, they are likely to be familiar with much of the basic material covered here. That said, it is important that trainers keep in mind the main purpose of the session – to engage those experienced teachers with some of the deeper ideas in Computer Science they may not be familiar with.

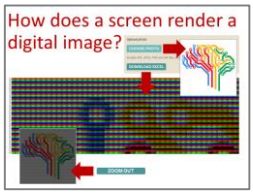
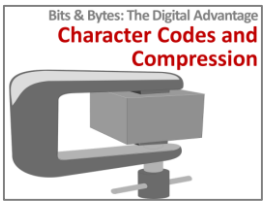
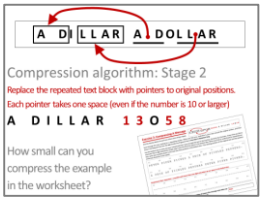
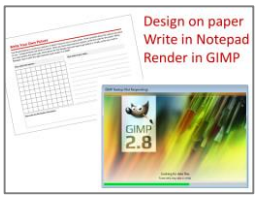
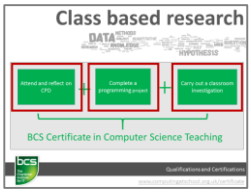
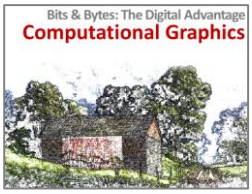
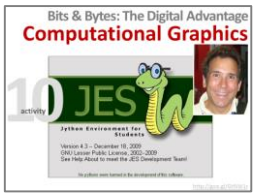
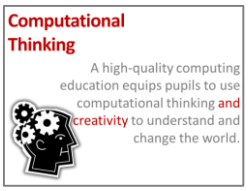
There are lots of quick exercises and supplementary material. The pace should be fast, with the assumption that the audience are probably already teaching to GCSE level, with some familiarity with the concepts of Computer Science. As such they will probably not need to work through every activity in full. Sometimes it will be sufficient to only part complete an activity so teachers 'get it' and can see how it might be used. What many may not be familiar with are some of the deeper details, for example, the role of demosaicing algorithms in digitising an image, Bresenham's algorithm for rendering a line or Lempel-Ziv compression. Please ensure time is allowed to cover this sort of content as well as sampling the activities. The day builds to a main practical activity where there is an assumption that the audience are able to code and probably have some familiarity with basic Python. Judgement is required and the timings below are indicative, to help with planning. Always be flexible and encourage discussion and engagement. Details of each activity are given in the teachers notes. Further guidance on the narrative, slide transitions and animation can be found in the slide notes.

Indicative Timetable

There are five sessions included in the day, the last one making a lengthy afternoon session. This could easily be expanded to a major half day cpd session. The previous four sessions offer a variety of activities, many of which may need only a cursory explanation. Please ensure you leave enough time for the last session, particularly if attendees have little familiarity with Python.

The trainer's presentation is broken down into 5 sections, with formal inputs and practical activities outlined below:

 15 minutes	Establishes key outcomes from the day for teachers (5 mins).  Quickly consider the requirements of the national curriculum but set the session in the context of the key educational goal: developing computational thinking (5 mins). Introduce the session by considering a computer system as a hierarchy of abstractions. End by emphasising the trend to greater digitisation and the benefits of digital representation. (5 mins)
 45 minutes	Introducing 3 activities:  Establishing the basics (15 mins) considers ways to introduce binary in the classroom. A little binary magic (15 mins) delves deeper into binary searches. Bytes, binary and bitmaps (15 mins) is a reinforcement activity that links to b/w pixel graphics and simple calculation of file size.

 60 minutes	Distinguishing between digitising and rendering and introducing image resolution and file size (10 mins). Full colour, hexadecimal/decimal conversion and html colour codes (10 mins). Practical activity: Pixel Spreadsheet (20 mins). Practical taught input: LCD displays and image capture technology (15 mins).	
 60 minutes	Group activity: Devising a character code (10 mins). Introducing hex editors, file analysis, size and Huffman coding (10 mins). Shrinking a message demonstration and activity (30 mins).	
 45 minutes	Investigating netpdm format in GIMP (20 mins). Run Length encoding / lossless and lossy compression / alternative representations of bitmaps (20 mins).	
 10 minutes	A short discussion to promote classroom research and encourage reflective practice. Draw out suggestions for potential research areas and mention possible techniques. Ends with a quick promotion of the BCS Certificate in Computer Science Teaching	
 90 minutes	Major practical activity using Python and JES to explore coding image manipulation techniques. This is easily extended and can cater for a range of experience. Taught input with live coding exemplars (45 mins) Practical exploration of activities in teacher notes developing range of algorithms e.g. edge detection, colour tints (45 mins).	
 10 minutes	Final summary emphasising creativity as well as computational thinking. Exemplar animated gif / coding activity (10 mins).	

Above all else, remember that the aim is to empower the attendees to offer similar sessions to colleagues. The central goal is to build confidence and a desire to spread the message. It should be inclusive, enjoyable and embody the CAS ethos of collegiality: There is no 'them', only us!

When someone books to attend the training session, send a prompt acknowledgment informing them when final confirmation and further details will be sent. Set a cut-off date, at which point you decide if there are enough bookings to make a viable session.

Once you have enough people booked, contact them again with brief details and suggested prior reading. Although not essential, by suggesting some prior reading you are indicating that this is in depth CPD which requires some commitment on the part of the attendees. It also gives you a chance to establish some dialogue with attendees prior to the event. With a week to go, you could mail a reminder and enquire about the reading and whether it would be useful for teaching. This helps keep the attendees focused on the event.

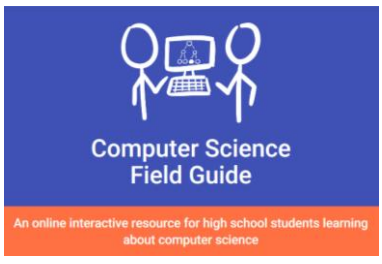
To allow it to focus on pedagogy and avoid too much time getting used to software it would be advantageous for all attendees to have had some initial experience of Python before the event. The main activity makes use of an educational utility, JES. This is included in the resources and needs to be installed on the computers used for the session. If they are bringing their own computers, it needs to be installed prior to the event, but no familiarity is needed, other than to ensure it works. It can be downloaded from goo.gl/GtNW1r. Another activity requires GIMP to be installed. This is free software available from gimp.org.

Prior Reading

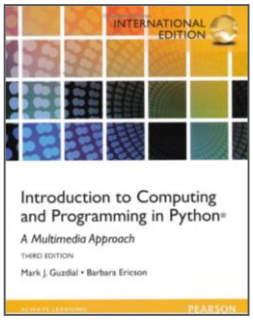
Basic binary, bits and bytes is the 'meat and drink' of most computing teaching. As such, one would expect attendees to be well versed in this area, the focus of the day being to look at interesting ways to introduce the material. The unit therefore has a practical flavour with explorations predominantly in image manipulation. The focus, as always is on computational thinking. To make that point, an interesting article to circulate prior to the event is a short story, 'A God Like Heart'. Paul Curzon, from QMUL, editor of the free magazine and CS4FN website, translated the story from Spanish and it is available from goo.gl/h0sSfw.

In a similar spirit of encouraging attendees to think of interesting ways to teach this traditional material encourage attendees to read three short instalments of Jeremy Kubica's Computational Fairy Tales. Both goo.gl/Ck4cSh and goo.gl/6U1wlC are easy introductions to binary which young children may like, whilst goo.gl/4CMmJI introduces pixels.

Further Reading



Two resources provided inspiration for much of the material covered in the session. Firstly the CS Field Guide from New Zealand (goo.gl/pgpg4h) has excellent chapters on data representation and compression, including lots of 'interactives' to try. From the folk who gave us Computer Science Unplugged, this is still a work in progress but is fast becoming one of the best reference sources for students. You might be encouraged to go further and read the encryption and error correction chapters too.



If the exercises using JES are inspiring Mark Guzdial's book, Introduction To Computing and Programming in Python: A Multimedia Approach is well worth exploring, along with the support material available from the media computation website (goo.gl/oadaqH). This is not just about writing routines to implement visual effects but provides an excellent grounding in computational concepts through a variety of explorations in multimedia. Watch his TEDx talk (available via the link above) and you'll quickly be inspired!

Well before the session is due to take place ensure you have considered computer access. Check whether attendees will be logging on to institution machines or bringing their own laptops. If BYOD, ensure that is made clear in any prior publicity and the software required for the session is signposted. Check that the venue has a projector and speakers.

As mentioned previously, GIMP and JES (both free) are used for this session. Ensure these are installed and work. Access to the internet is required by attendees.

Note also that several of the activities require files to be shared. These include sample netpbm files for opening in GIMP and the wonderful Pixel Spreadsheet utility. If using computers provided by the institution, access to a shared repository is the ideal method of distribution. If colleagues are bringing their own devices, some thought will be needed as to how to distribute these files. They are all available, along with the handouts from the Tenderfoot resource links.

Ensure you have the following general material:

- Facilities for taking notes (paper and pens)
- A3 Computational Thinking Posters
- CAS publicity: Copies of SwitchedON, BCS Certificate flyers and any local information

Attendee / Trainers Materials and Resources

Attendee materials are in black, requiring one copy per person. Supplementary trainer's material for demonstration purposes are in red (single copies).

Activity	Materials (Per Attendee)	
It's All Done By Numbers	Binary Cards	☐
	Super Switching Binary Machine + Post-It Notes	☐
	Australian Magicians Dream Handout + sets of cards (and duplicate) to try	☐
	Set of cards for trick above (plus envelope and large duplicate)	☐
	Set of binary punched cards + knitting needle	☐
	Binary bitmap spreadsheet challenges e-resources	☐
	Teachers Notes	☐
Playing With Pictures	Digitising Images Resource Sheets	☐
	Crossbin Puzzles	☐
	Tarzia Sample Matching Exercises	☐
	Pixel Spreadsheet e-resource	☐
	Teachers Notes	☐
Character Codes and Compression	Ascii Decoder Wheel	☐
	Ascii Binary Decimal Tables (and 8 paper cups each)	☐
	Compression Exercises (3)	☐
	Teacher Notes	☐

Continued overleaf

Painting By Numbers	Netpbm sample files e-resource Write Your Own Picture Exercises (Easy or Hard) Run Length Encoding Exercise Logical Picture Puzzles Teacher Notes	☐ ☐ ☐ ☐ ☐
Computational Graphics	Teachers Notes (handout for all as exercises)	☐
Reflective Practitioner	BCS Certificate Flyers Trainers Notes	☐ ☐

The slide presentation is designed to support a full one day session, delivered to CAS Master Teachers and other curriculum champions. It will likely be fast paced, delivered to experienced teachers. Two sessions in particular focus on practical activities. Although indicative timing are given, both Playing With Pictures and Computational Graphics could be extended to form longer sessions with more time for the practical challenges.

It is envisaged that those attendees will take the material and deliver shorter sessions, either as half day, twilight or CAS Hub inputs. It is expected these will take longer to cover each activity as the material will be unfamiliar to teachers new to Computer Science. Please find time to discuss with attendees possible ways to use the material and encourage them to offer further sessions in their locality.

Resources

All supporting material is available for download, corresponding to each session in the Unit.

The material includes

- a full presentation to support all the activities covered in the Unit
- a set of Teachers Notes explaining the material for each session
- separate activity handouts

If you intend to use the material at shorter sessions, simply hide the slides not used.

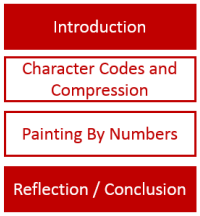
If you wish to combine material in a different order please consider adding slides to introduce the 'big picture' at the start and to discuss being a reflective practitioner at the end. Please try to stick to the CAS House Style which is outlined on the opening introduction slide.

Half Day / Twilight CPD Sessions

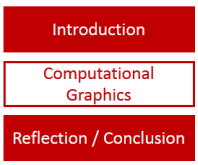
It is suggested the material could be delivered as 3 separate shorter sessions:

A session aimed at those new to computer science could combine the basics of binary (All Done By Numbers) with an exploration of digital images and a practical session using Pixel Spreadsheet.

The practical challenges that can be set for manipulating pixel values in Pixel Spreadsheet could be varied to make this a very flexible session.



Combining Character Codes and Compression with Painting By Numbers provides a session aimed perhaps at more experienced colleagues with a focus on material that might be worthwhile at gcse level, in particular the compression activities and exploration of file formats. Again, both the exploratory activities for designing character codes and the practical challenges 'writing' pictures can be extended or curtailed to suit time available.



A session exploring computational graphics using JES could be extended to include Pixel Spreadsheet as an introductory activity. This is the most challenging of the areas and assumes some prior familiarity with programming (and ideally Python syntax).

Such is the scalable nature of the challenges it could easily form a full day session.

The three suggested sessions provide some degree of progression. Each should be topped and tailed with the Introduction and Conclusion slides, though these may benefit from being edited to avoid repetition. Of course, Master Teachers and other trainers can combine activities in ways they feel best fit local needs. Many are short enough to introduce at CAS Hubs or worked through in a school departmental meeting. Whatever ways you choose, we hope they are useful.