OTS Masterclass - Digital Computers

Session Leader Notes

Inspiration:

Since ancient times, humans have used their fingers for counting and calculations. We use the word 'digit' to mean both a finger and a numeral. Through the demonstrations and activities in this session, students will learn about ways that they too can be 'digital computers' and find out about binary numbers, a crucial component of real digital computing today.

Overview of Activities:

- Counting on fingers
- Multiples of nine trick
- Multiplying with your fingers trick
- Mind reading trick
- Counting in binary
- Binary and decimal worksheets

General Masterclass resources needed:

- Register of children
- Consent forms and emergency information to hand
- Stickers and markers for name badges
- Adult register
- Ri child protection policy
- Paper and pencils/whiteboards for workings
- 2 different coloured post it note pads (for feedback at the end)
- Drinks and biscuits

Specific resources needed (printable worksheets in worksheet folder):

- Post-it notes cut into strips, to wrap and stick around fingertips - sets of five per student with spares (some may wish to use ten for the multiplication trick, but everyone will need 5 for binary counting)
- Mind reading cards (sheets printed, in colour if possible, and cut into six horizontal strips, one strip per student)
- Converting between binary and decimal worksheets - two sheets, one each per student
- Writing your name in binary worksheet - one per student (optional extra activity if desired)
- 'Counting in binary' cheat sheet with fingers needed shown - as needed

Support resources:

- Helper notes: An overview of the Masterclass content and activities
- Supporting notes: Extra information and background on the content of this Masterclass
- Session script: Suggested wording for each section of the session

Things to prepare in advance

- Print worksheets and resources as detailed above, and cut up Mind Reading cards
- Gather general Masterclass resources
- Cut post-it notes into strips to label students' fingers with and make up sets of five

Ask the Ri

Don't forget to collect any questions which arise, and email them to the Masterclass team at the Royal Institution: masterclasses@ri.ac.uk

Feedback

We would very much welcome your feedback on this session. If you have time, please collect feedback from the students at the end of the Masterclass and send it through to us. We would also appreciate feedback on how you have used the session, what you think worked well and what improvements would be useful.

Time plan of Masterclass:

Slides & Time	Overview	Activity
Slide 1-2 5 minutes (5)	Introduction Instructions on screen. Helper and Speaker circulating and chatting with students	Settling activity - how do you count on your fingers? Students should compare methods and try some of the examples given on the board. Does anyone know any other methods? Chinese and Japanese finger counting work differently.
Slides 3-9 5 minutes (10)	Introduction to the Ri *[Only include these slides for the first session in the series – otherwise remember to hide the slides before you start the Masterclass]*	Use these slides to introduce the students to the work of the Ri and other ways they can get involved – see notes on the slides for more detail. In particular: • The Ri is a science communication charity which has been around since 1799. We've got a huge amount of history and lots of famous scientists lived and worked at the Ri. Most importantly, we've always been about communicating science to the general public – and that's something we still do today. We do talks and activities for the public as well as with schools all across the UK. • There are lots of family events at our building in London, including family fun days and holiday workshops just like the Masterclasses. • The CHRISTMAS LECTURES are for young people and are on television at Christmas time, looking at a different topic every year. We've got an archive on our website of all of the recent series plus many of the older ones. The CHRISTMAS LECTURES are what started the Masterclass programme. See slide notes for links. • We have a YouTube channel with lots of videos for people interested in science (and maths engineering, computer science…), especially our ExpeRimental series which is all about doing experiments at home. • Students are part of a big family of Masterclass attendees – we have been running Masterclasses since 1981. • Students at series running within reach of London will be invited to a Celebration Event at the Ri in June/July. • You can become an Ri Member to get more involved with what we do (and enter the ballot to buy tickets to the CHRISTMAS LECTURES filming).
Slides 10-13 5 minutes (15)	Explanation of finger counting and calculation	Explain to students that the workshop is called 'digital computing' because people historically have used their fingers to count and calculate, so the word 'digit' means both a finger and a numeral. Use the slides to explain that the symbols for 1, 2 and 3 are developed from earlier symbols made up of 1, 2 and 3 strokes to represent fingers. You can also explain that the words for 'five' and 'fist' are similar in many languages, as they are from the same root. Students may wish to research this kind of connection more themselves. In this workshop we're going to see some ways to use your fingers to count and make calculations.
Slides 14-24 15 minutes (30)	'Multiples of nine' and 'multiplying numbers' finger tricks	Students may already know about a trick for working out multiples of nine quickly - use the slides to explain that if you want to work out nine times something (where 'something' is between 1 and 10) they simply need to put down the finger corresponding to that number, and the number of fingers either side of the gap will be the two digits of the result. Let them

		practise a little, and try some examples. Ask the students to think about why this trick works - what does it mean to add 9? It's the same as adding 10 and subtracting 1, so this will increase the tens digit and decrease the units digit each time. The next trick is slightly harder - number your fingers 6 - 10 as shown on the slide, on each hand. Touch the fingers together which correspond to the two numbers you'd like to multiply, then the result will be (10 × the number of fingers below the bridge, including the bridge itself) + (number of fingers above the bridge on the left × number of fingers above the bridge on the right). The example given on the slides is 8 × 9 = 72. Explain the trick to the students and allow them some time to practice and try the examples on the slide. The slide includes a hand with the fingers labelled, so they can remember the numbers. Acknowledge that sometimes this trick might not be easier than just knowing your times tables!
Slide 25 10 minutes (40)	Mind reading trick	Next we have a really impressive trick. Give the students the mind reading cards, and ask them to think about specifically the date in their birthday (which should be a number between 1 and 31). They should look at the cards and decide which cards their number is on, and which it's not on. You should be able to ask any student to tell you which cards have their birthday, and in reply guess when their birthday is - using the numbers in the top left of the cards, you can add together the powers of two, 1, 2, 4, 8 and 16 if those cards contain their birthday number. For example, if they tell you their birthday is on cards 0, 2 and 3 you'd add $2^0 + 2^2 + 2^3 = 1 + 4 + 8 = 13$. Don't reveal to students how the trick is done, but ask them to think about the numbers on the cards, and if they're unsure, in particular the first number on each card, and ask them to work out how to do the trick. At this stage, they can think of it as simply adding together the numbers in the top left. Then give them a chance to try it on each other - guessing what number someone is thinking of, if you already know their birthday.
Slides 26-30 15 minutes (55)	Mind reading trick - explanation and binary counting	Start by asking students what's special about the numbers in the top left of the cards - they're powers of two, and the number doubles to go from each one to the next. Explain that these numbers are special, because you can use them to make any other number by adding them together - but what's even better is you never need to use each number more than once. For example, 6 = 2 + 4. Then if we want to find a way to make 10, we could say 10 = 2 + 4 + 4. But we don't need to use two fours, because the next number along is 8, which is just two fours - so we could say 10 = 2 + 8. The fact that the numbers double mean we never need more than one of each. This means we can use our fingers to count using these numbers! Give the students strips of post-it note with a sticky bit to wrap around each of their fingers, to label them 1, 2, 4, 8 and 16 (from the little finger as 1 up to thumb as 16, to match the slides, and with the numbers on the palm side to avoid rude gestures), then see if how high they can count just putting their fingers up and down. If they can count all the way up to 31 on one hand, ask them to challenge each other to display specific numbers. We've also included a 'cheat sheet' with diagrams of

		all the finger positions on a left hand.
10 mins (65)	BREAK	Drinks and biscuits and comfort break
Slides 31-38 15 minutes (80)	Binary worksheets	Give students the worksheets about converting numbers from decimal to binary (there's a simple one with numbers up to 7 and a harder one with some examples and space for them to come up with their own), and ask them to fill in the rows - instead of putting fingers up and down, we can use yes and no, or 1 and 0 to show how many of each number we'll use. Explain that computers use binary to store and calculate numbers, and they may have heard of binary as being made of 1s and 0s - this is why you never need a 2, because these numbers allow you to only use 0 or 1 of each. There's also a sheet for converting your name into binary if you'd like another activity to do here. What might the next column be if we were to use more than 5? If we labelled all the fingers on both hands, what's the largest number we could represent? (hint: this would mean all the fingers would be used, so you'd need to add together the numbers on all ten fingers, which go up as far as 512).
Slides 39-43 10 minutes (90)	Relating binary to other bases	Explain that this system is actually similar to the system we normally use, except instead of multiplying by 2 to get the next column heading we normally multiply by 10, and write numbers as 1s, 10s, 100s, 1000s etc. This time we need more than 0 or 1, because we need to make all the numbers in between, so we might need 0, 1, 2, 3, 4, 5, 6, 7, 8 or 9 of each. Link this back to the fact that humans have 10 fingers, so this is the natural way to represent numbers. Some systems use other number bases - hexadecimal is a system some computer systems use which has 16 digits, and the column headings multiply by 16 each time. This means they need more symbols, and they actually use 0-9 and A-F. This means you can write bigger numbers using fewer digits. The ancient Mayans used a system which incorporated base 20, called vigesimal, and had 20 different symbols to represent numbers.
Slides 44-48 5 minutes (95)	Feedback, tidy up, questions time Ask the Ri	Recap of session contents. Don't forget to collect any questions and feedback on post-it notes, and email them to the Masterclass team at the Royal Institution: masterclasses@ri.ac.uk
Slides 49-52	Possible NRICH problems related to this session – use as extension activities or for them to do at home	nrich.maths.org/1368 - Learn about number bases nrich.maths.org/829 - Basically nrich.maths.org/5722 - Alien counting nrich.maths.org/1131 - Back to the planet of Vuvv