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QuickStart Computing

A CPD toolkit for primary teachers

FUNDED BY

Department for Education

Microsoft

Foreword

September 2014 saw the introduction of the new national curriculum in England and, for the first time, schools must teach computing.

For most of us, technology and computers play a vital role in our lives: at home, at work, for our health and for our informal learning. It is important that our children learn how this stuff works, rather than treating it as magic. Just as we teach the traditional sciences in primary school and into secondary school, we must now teach *computer science*, the '*fourth science*', to ensure children leave school equipped with the skills and knowledge they need to participate effectively in society, whether or not they go on to become computing professionals.

QuickStart Computing has been developed to support schools with the new programme of study, by providing you with the resources you will need to successfully run your own computing CPD course for colleagues in your school, cluster, or area. This pack will give you the essential subject knowledge you need, with a framework and guidance for planning, teaching and assessing progress.

This *QuickStart* resource is focused on key stages 1 and 2, but there is a companion pack for KS 3 and 4.

A word about sponsorship. The *QuickStart* project was funded by Microsoft, with matched funding from the Department for Education, and it is heartening to see such tangible support for teachers, both from business and from government. I would like to thank both of them warmly and to emphasise that the *QuickStart* resources were developed for you by a Computing At School working group, without the direct influence of either sponsor.

The computing curriculum is a once-in-a-lifetime opportunity for schools to make a difference to children's futures. Let's make the most of it! I hope that *QuickStart* will help you design, develop and deliver an invigorating computing curriculum that will inspire you and your children.

Simon Peyton Jones
Chair, Computing At School

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Contents

User guide

Welcome to *QuickStart Computing*: a CPD toolkit for the new primary curriculum. Computing is a new subject. It draws together the strands of computer science, information technology and digital literacy, and seeks to equip children with computational thinking skills and the creativity they need to understand and change the world.

Through the programme of study for computing, primary school-aged children learn the fundamental principles and processes of computation; they gain repeated, practical experience of writing code to solve problems and to model systems; they also become skilled at creating high quality products and content using digital technology; and they become safe, responsible and critical users of technology.[1] Computing is an enjoyable and empowering subject to learn, and it's a very rewarding one to teach. However, unlike other subjects in the primary curriculum, it's not one many primary teachers learned themselves when they were at school, or were taught about in their teacher training.

What is QuickStart Computing?

Quickstart Computing is a set of resources that address the subject knowledge and the subject-specific pedagogy teachers need in order to plan, teach and assess the primary computing curriculum effectively and confidently.

This handbook is broken down into three sections:

- Computing subject knowledge with suggestions for tried-and-tested classroom activities to run in school (see pages 6–49)
- Advice for planning, teaching and assessing the computing curriculum (see pages 50–55)
- Guidance for running computing CPD sessions (see pages 56–59).

All three sections are supported by:

a selection of videos to explain particular computing concepts and ideas; the video content is highlighted at the start of each subject knowledge section

weblinks to useful information, including activity ideas from Computing At School, Barefoot Computing and CS Unplugged.

All the resources are available to download free of charge from www.quickstartcomputing.org.

[1] National Curriculum in England, *Computing Programmes of Study* (Department for Education, 2013).

Delivering computing CPD

This toolkit can be used to develop and deliver computing CPD sessions to colleagues and computing coordinators. We have suggested a model for the use of this CPD on the page opposite but you can decide how best to share the training to meet the needs of your school, cluster or hub.

All timings and durations are suggestions only and should be adapted to fit with the needs of both the course leader and session attendees. For example, the diagram opposite outlines two half-day CPD sessions to take place at the beginning and end of a school term, but depending on availability of session leaders and attendees, it may be better to hold three shorter twilight sessions.

These resources are designed to be used flexibly and it is important to spend time reviewing the materials provided and developing these prior to delivering CPD sessions, to ensure they fit the needs of your attendees. The CPD session presentations are provided in editable format to help you with this.

Developing computing knowledge and skills

To benefit most from these resources, it's important to engage fully with them.

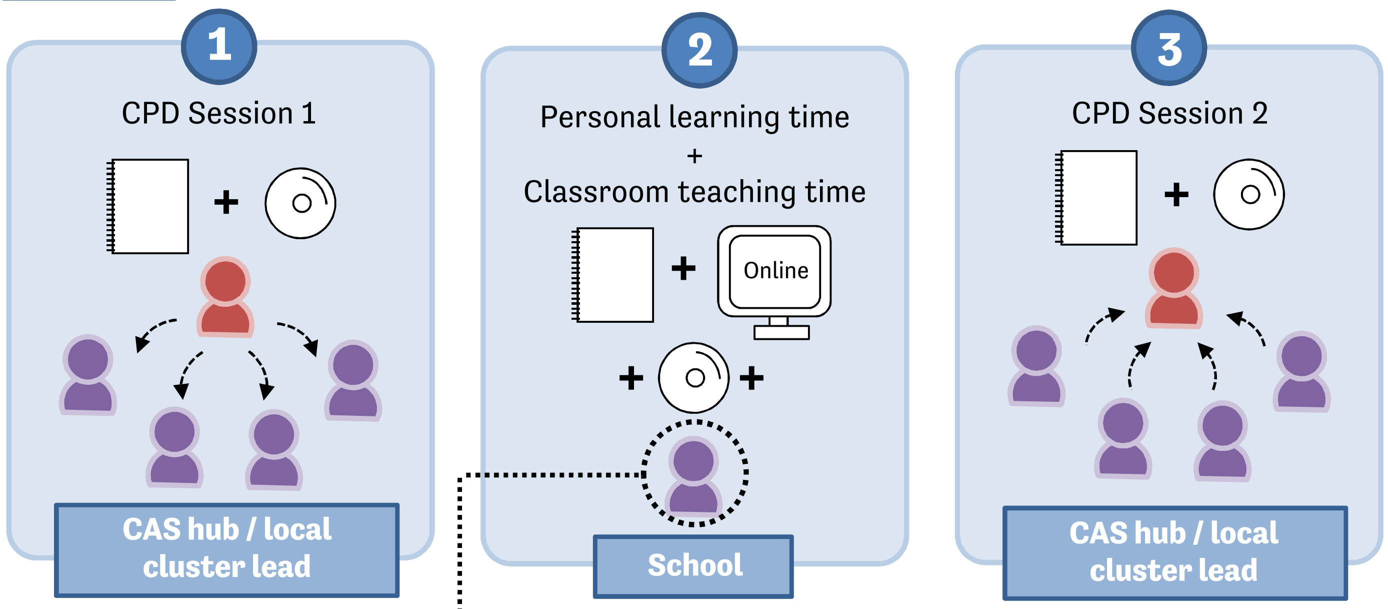
- Read the handbook, particularly those areas of content in which you are less confident (see pages 62–63 for the knowledge and skills audit form, and the interactive audit tool is at www.quickstartcomputing.org).
- Have a go at creating some code, for example making games in Scratch or Kodu; think about how you would apply these ideas in school.
- Look for existing examples of computational thinking that you make use of in your job.
- Try out some of the classroom activities described in the handbook.
- Engage with others. Learning as part of a group allows you to share knowledge and ideas. This can be done in school and by joining an online community such as Computing At School: www.computingatschool.org.uk/.

For more information about developing your computing knowledge and skills beyond this toolkit, see Next steps on page 60.

Note: throughout the guide we have highlighted computing terms in **blue**. The definitions of these terms are in the glossary on page 64.

QuickStart Computing roadmap

Wave 1

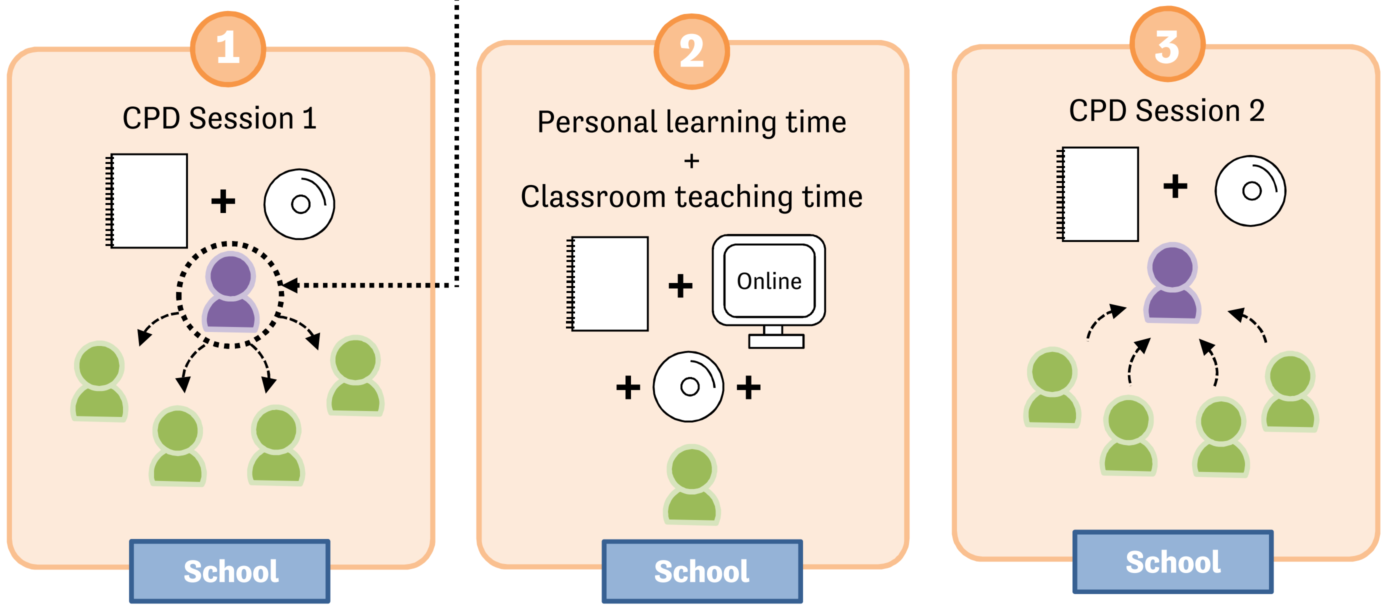


Local computing champion introduces Computing course to computing coordinators at local meeting.

Computing coordinators use the CPD resources to develop personal knowledge and practise teaching activities in classroom.

Computing coordinators re-group at local meeting for a de-brief on learning experiences and discuss next steps.

Wave 2



Computing coordinators lead face-to-face CPD concept sessions in school with colleagues.

Class teachers use the CPD resources to develop personal knowledge and practise teaching activities in classroom.

Class teachers re-group in staff meeting for a de-brief on learning experiences and discuss next steps.

● Local computing champion ● Computing coordinator ● Class teacher

Computational thinking

- Introducing algorithms
- Logical reasoning

How do we think about problems so that computers can help?

Computers are incredible devices: they extend what we can do with our brains. With them, we can do things faster, keep track of vast amounts of information and share our ideas with other people.

What is computational thinking?

Getting computers to help us to solve problems is a two-step process:

1. First, we think about the steps needed to solve a problem.

2. Then, we use our technical skills to get the computer working on the problem.

Take something as simple as using a calculator to solve a word problem in maths. First, you have to understand and interpret the problem *before* the calculator can help out with the arithmetic bit.

Similarly, if you're going to make an animation, you need to start by planning the story and how you'll shoot it *before* you can use computer **hardware** and software to help you get the work done.

In both of these examples, the thinking that is undertaken before starting work on a computer is known as **computational thinking**.

Computational thinking describes the processes and approaches we draw on when thinking about problems or systems in such a way that a computer can help us with these.

Computational thinking is *not* thinking about computers or like computers. Computers don't think for themselves. Not yet, at least!

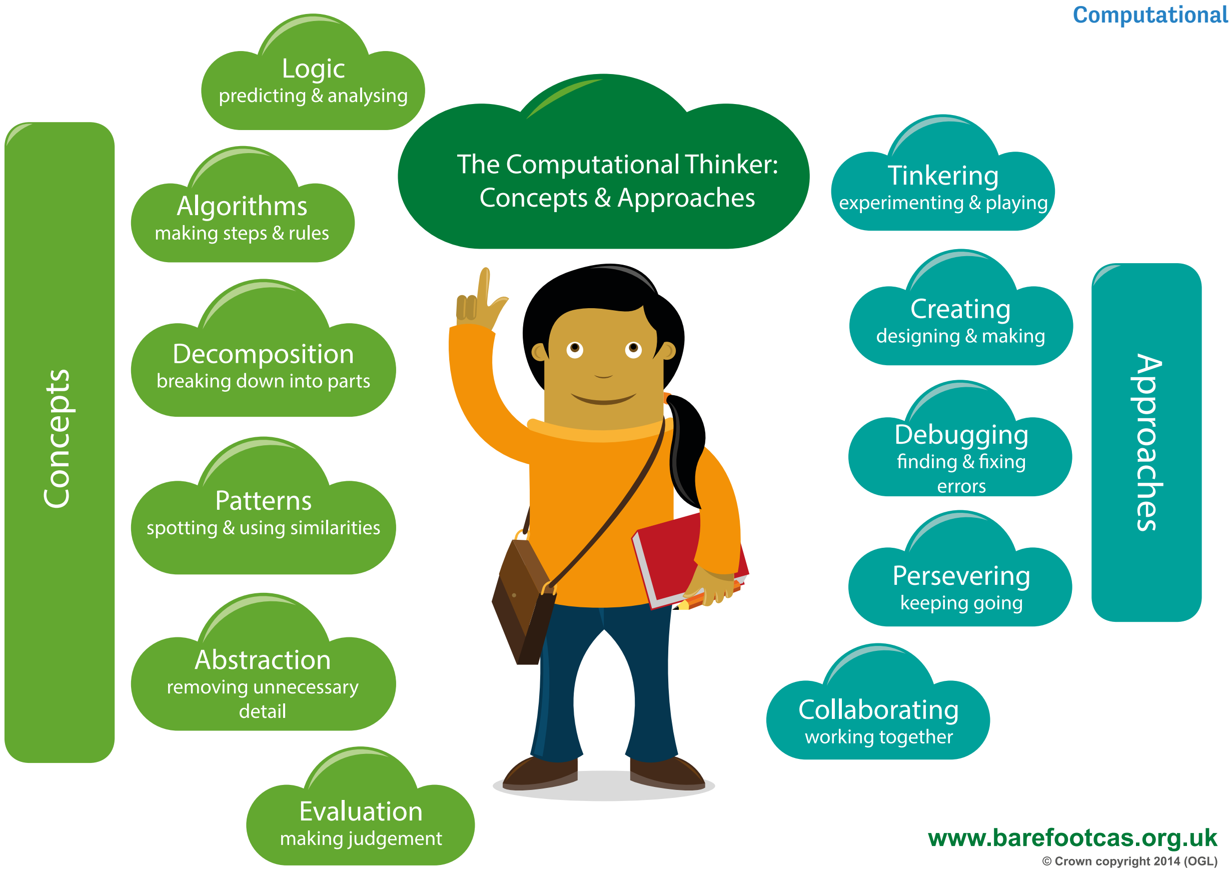
Computational thinking is about looking at a problem in a way that a computer can help us to solve it.

When we do computational thinking, we use the following processes to tackle a problem:

- Logical reasoning: predicting and analysing (see pages 8–10)
- Algorithms: making steps and rules (see pages 10–12)
- Decomposition: breaking down into parts (see pages 12–14)
- Abstraction: removing unnecessary detail (see pages 14–15)
- Patterns and generalisation: spotting and using similarities (see pages 15–16)
- Evaluation: making judgements

What can you do with computational thinking?

Although computational thinking describes the sort of thinking that computer scientists and software developers engage in, plenty of other people think in this way too, and not just when it comes to using


The Computational Thinker: Concepts & Approaches
Concepts
Logic predicting & analysing
Algorithms making steps & rules
Decomposition breaking down into parts
Patterns spotting & using similarities
Abstraction removing unnecessary detail
Evaluation making judgement
Approaches
Tinkering experimenting & playing
Creating designing & making
Debugging finding & fixing errors
Persevering keeping going
Collaborating working together
www.barefootcas.org.uk
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computers. The thinking processes and approaches that help with computing are really useful in many other domains too.

For example, the way a team of software engineers go about creating a new computer game, video editor or social networking platform is really not that different from how you and your colleagues might work together to put on a school play, or to organise an educational visit.

In each case:

- you take a complex problem and break it down into smaller problems
- it's necessary to work out the steps or rules for getting things done
- the complexity of the task needs to be managed, typically by focusing on the key details
- the way previous projects have been accomplished can help.

How is computational thinking used in the curriculum?

Ideas like logical reasoning, step-by-step approaches (algorithms), decomposition, abstraction and **generalisation** have wide applications to solving problems and understanding systems across (and beyond) the school curriculum. There are many ways to develop these in school beyond the computing curriculum, but as pupils learn to use these in their computing work, you should find that they become better at applying them to other work too.

You will already use computational thinking in many different ways across your school.

- When your pupils write stories, you encourage them to plan first: to think about the main events and identify the settings and the characters.
- In art, music or design and technology, you will ask pupils to think about what they are going to create and how they will work through the steps necessary for this, by breaking down a complex process into a number of planned phases.
- In maths, pupils will identify the key information in a problem before they go on to solve it.

Where does computational thinking fit in the new computing curriculum?

The national curriculum for computing puts computational thinking right at the heart of its ambition. It states:

A high-quality computing education equips pupils to use computational thinking and creativity to understand and change the world.[1]

[1] National Curriculum in England, *Computing Programmes of Study* (Department for Education, 2013).

Whilst programming (see pages 18–29) is an important part of the new curriculum, it would be wrong to see this as an end in itself. Rather, *it's through the practical experience of programming that the insights of computational thinking can best be developed*.

Computational thinking shouldn't be seen as just a new name for 'problem-solving skills'. It does help to solve problems and it has wide applications across other disciplines, but it's most obviously apparent, and probably most effectively learned, through the rigorous, creative processes of writing code – as discussed in the next section.

Classroom activity ideas

- Ask your pupils to write a recipe for a sandwich, thinking carefully about each step that needs to be carried out. Point out that the step-by-step sequence of instructions is an algorithm. Ask them to share each other's recipes and spot patterns in them (this is called generalisation). Read a range of recipes and discuss the layers of simplification (abstraction) present in even relatively simple recipes, such as for pizza.
- Plan a traditional 'design, make and evaluate' project for design and technology, drawing out the parallels with computational thinking. For example, plan the process for making a musical instrument. Tell the pupils to break this complex problem down into smaller stages, such as:
  - » planning their design (an abstraction – a simplified version – capturing the key elements of this)
  - » sourcing their materials (using decomposition to identify the different components)
  - » assembling the materials to create the instrument (a systematic, step-by-step approach – an algorithm)
  - » evaluating (testing) the instrument.
- Challenge older pupils to work individually or collaboratively on more complex projects, for example researching and writing up aspects of a curriculum topic such as the Viking invasion, or putting together an assembly or a class play. In each case ask them to note down the individual steps needed for the task and to think about what they have left out to make the subject fit their brief.

Further resources

- Barefoot Computing, 'Computational Thinking', available at: http://barefootcas.org.uk/barefoot-primary-computing-resources/concepts/computational-thinking/ (free, but registration required).
- Berry, M., 'Computational Thinking in Primary Schools' (2014), available at: http://milesberry.net/2014/03/computational-thinking-in-primary-schools/.
- Computer Science Teachers Association, 'CSTA Computational Thinking Task Force' and 'Computational Thinking Resources', available at: http://csta.acm.org/Curriculum/sub/CompThinking.html.
- Computing At School, 'Computational Thinking', available at: http://community.computingatschool.org.uk/resources/252.
- Curzon, P., Dorling, M., Ng, T., Selby, C. and Woollard, J., 'Developing Computational Thinking in the Classroom: A Framework' (Computing At School, 2014), available at: http://community.computingatschool.org.uk/files/3517/original.pdf.
- Google for Education, 'Exploring Computational Thinking', available at: www.google.com/edu/computational-thinking/index.html.
- Wing, J., 'Computational Thinking and Thinking about Computing' (The Royal Society, 2008), available at: http://rsta.royalsocietypublishing.org/content/366/1881/3717.full.pdf+html.

Logical reasoning

Can you explain why something happens?

If you set up two computers in the same way, give them the same instructions (the program) and the same **input**, you can pretty much guarantee the same **output**.

Computers don't make things up as they go along or work differently depending on how they happen to be feeling at the time. This means that they are predictable. Because of this we can use *logical reasoning* to work out exactly what a program or computer system will do.

Children quickly pick this up for themselves: the experience of watching others and experimenting for themselves allows even very young children to develop a mental model of how technology works. A child learns that clicking the big round button brings up a list of different games to play, or that tapping here or stroking there on the screen produces a reliably predictable response.

This process of using existing knowledge of a system to make reliable predictions about its future behaviour is one part of logical reasoning. At its heart, logical reasoning is about being able to explain why something is the way it is. It's also a way to work out why something isn't quite as it should be.

How is logical reasoning used in computing?

Logic is fundamental to how computers work: deep inside the computer's central processing unit (CPU), every operation the computer performs is reduced to logical operations carried out using electrical signals.

It's because everything a computer does is controlled by logic that we can use logic to reason about program behaviour.

Software engineers use logical reasoning all the time in their work. They draw on their internal mental models of how computer hardware, the **operating system** (such as Windows 8, OS X) and the programming language they're using all work, in order to develop new code that will work as they intend. They'll also rely on logical reasoning when testing new software and when searching for and fixing the 'bugs' (mistakes) in their thinking (known as **debugging** – see page 17) or their coding when these tests fail.

How is logical reasoning used across the curriculum?

There are many ways that children will already use logical reasoning in their computing lessons and across the wider curriculum.

- In English, pupils might explain what they think a character will do next in a novel, or explain the character's actions in the story so far.
- In science, pupils should explain how they have arrived at their conclusions from the results of their experiments.
- In history, pupils should discuss the logical connections between cause and effect; they should understand how historical knowledge is constructed from a variety of sources.

Where does logical reasoning fit in the new computing curriculum?

In the computing curriculum, key stage 1 pupils are expected to use logical reasoning to predict the behaviour of simple programs. This can include the ones they themselves write, perhaps with a floor turtle, or simple movement commands on screen in a program like Scratch, but it might also include predicting what happens when they play a computer game, or use a painting program.

At key stage 2, pupils are expected to 'use logical reasoning to explain how some simple algorithms work and to detect and correct errors in algorithms and programs'.[2]

Classroom activity ideas

- Provide pupils with floor turtles and ask them to make predictions of where the robot will end up when the go button is pressed. Then ask them to explain *why* they think that. Being able to give a reason for their thinking is what using logical reasoning is all about.
- In their own coding, logical reasoning is key to debugging (finding and fixing the mistakes in their programs). Ask the pupils to look at one another's Scratch or Kodu programs and spot bugs. Encourage them to test the programs to see if they can isolate exactly which bit of code is causing a problem. If pupils' programs fail to work, get them to explain their code to a friend or even an inanimate object (e.g. a rubber duck).
- Give pupils a program of your own or from the Scratch or Kodu community sites and ask them to work backwards from the code to work out what it will do.
- Ask pupils to think carefully about some school rules, for example those in the school's computer

[2] National Curriculum in England, *Computing Programmes of Study* (Department for Education, 2013).

Acceptable Use Policy. Can they use logical reasoning to explain why the rules are as they are?
- There are many games, both computer-based and more traditional, that draw directly on the ability to make logical predictions. Organise for the pupils to play noughts and crosses using pencil and paper. As they are playing, ask them to predict their opponent's next move. Let them play computer games such as Minesweeper, Angry Birds or SimCity, as appropriate. Ask them to pause at certain points and tell you what they think will happen when they move next. Consider starting a chess club if your school doesn't already have one.

Further resources

- Barefoot Computing, 'Logic: Predicting and Analysing', available at: http://barefootcas.org.uk/barefoot-primary-computing-resources/concepts/logic/ (free, registration required).
- Computer Science for Fun, 'The Magic of Computer Science', available at: www.cs4fn.org/magic/.
- Computer Science Unplugged, 'Databases Unplugged', available at: http://csunplugged.org/databases.
- McOwan, P. and Curzon, P. (Queen Mary University of London), with support from EPSRC and Google, 'Computer Science Activities With a Sense of Fun', available at: www.cs4fn.org/teachers/activities/braininabag/braininabag.pdf.
- The P4C Co-operative, a co-operative providing resources and advice on philosophy for children, available at: www.p4c.com/.
- PhiloComp.net, website highlighting the strong links between philosophy and computing, available at www.philocomp.net/.

Algorithms

What's the best way to solve a problem?

An algorithm is a sequence of instructions or a set of rules to get something done.

You probably know the fastest route from school to home, for example, turn left, drive for five miles, turn right. You can think of this as an 'algorithm' – as a sequence of instructions to get you to your chosen destination. There are plenty of algorithms (i.e. routes) that will accomplish the same goal; in this case, there are even algorithms (such as in your satnav) for working out the shortest or fastest route.

How are algorithms used in the real world?

Search engines such as Bing or Google use algorithms to put a set of search results into order, so that more often than not, the result we're looking for is at the top of the front page.

Your Facebook news feed is derived from your friends' status updates and other activity, but it only shows that activity which the algorithm (EdgeRank) thinks you'll be most interested in seeing. The recommendations you get from Amazon, Netflix and eBay are algorithmically generated, based in part on what other people are interested in.

Given the extent to which so much of their lives is affected by algorithms, it's worth pupils having some grasp of what an algorithm is.

How are algorithms used across the curriculum?

Helping pupils to get an *idea* of what an algorithm is needn't be confined to computing lessons. You and your pupils will already use algorithms in many different ways across the school.

- A lesson plan can be regarded as an algorithm for teaching a lesson.
- There will be a sequence of steps pupils follow for many activities, such as getting ready for lunch or going to PE.
- In cookery, we can think of a recipe as an algorithm.
- In English, we can think of instructional writing as a form of algorithm.
- In science, we might talk about the method of an experiment as an algorithm.
- In maths, your approach to mental arithmetic (or many computer-based educational games) might be an implementation of a simple algorithm.

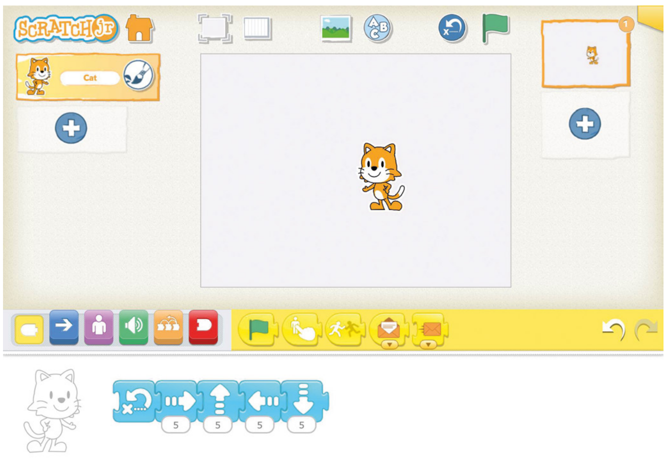
An example of this might be:

- repeat ten times:
  - ask a question
  - wait for a response
  - provide feedback on whether the response was right or wrong.

Where do algorithms fit in the new computing curriculum?

The computing curriculum expects pupils in key stage 1 to have an understanding of what algorithms are, and how they are used in programs on digital devices.

There can be many algorithms to solve the same problem, and each of these can be implemented using different programming languages on different computer systems: it can be useful for pupils to compare how they draw a square with a floor turtle and how they would do this on screen in Logo or ScratchJr.



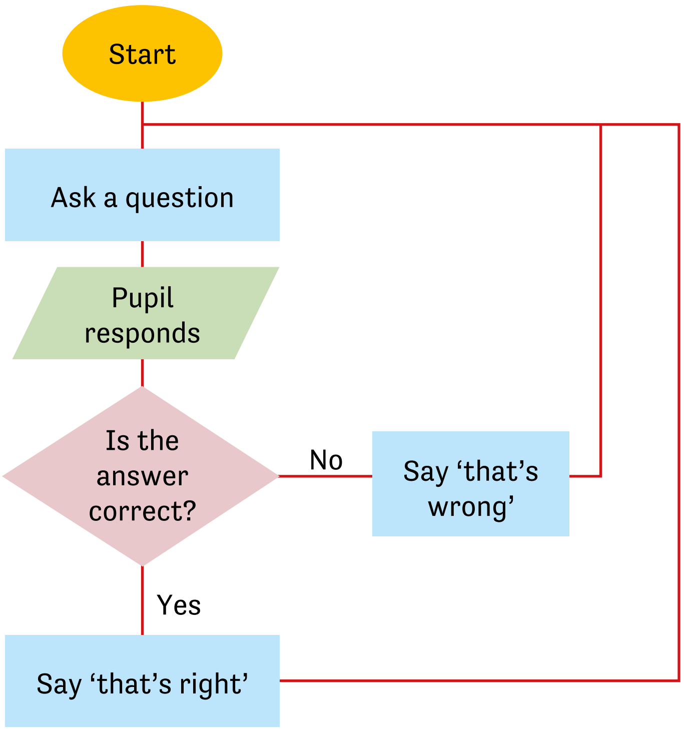
Scratch Jnr programming for drawing a square.

Key stage 2 builds on this: pupils are expected to design programs with particular goals in mind, which will draw on their being able to think algorithmically, as well as using logical reasoning (see pages 8–10) to explain algorithms and to detect and correct errors in them. To practise this, encourage pupils to carry out the steps for an algorithm: to follow the instructions themselves rather than writing these as code for the computer. Errors and inconsistencies should become apparent!

Whilst programming languages like Scratch and Kodu (see pages 21–22) can make it seem unnecessary to go through the planning stage of writing a program, it is good practice for pupils to write down the algorithm for a program, perhaps as rough jottings, a storyboard, pseudocode (a written description of how a program will operate) or even as a flow chart (see below). This makes it far easier for them to get feedback from you or their peers on their algorithms before implementing these as code on their computers.

```
Repeat 10 times:
      Ask a maths question
      If the answer is right then:
            Say well done!
      Else:
            Say think again!
```

An example of pseudocode.



An example of a flow chart.

Classroom activity ideas

- Talk to the pupils about what makes one algorithm better than another. In early programming work, pupils will come to realise that a Bee-Bot program which uses fewer steps than another to get to the same place is quicker to type and quicker to run.
- Play the classroom game 'Guess my number' to demonstrate this. Tell the pupils that you have

chosen a number between 1 and 100 and they are to guess what it is. Tell them that they can ask you questions about the number but that you can only answer 'yes' or 'no', and that they can only ask you one question per pupil.

- » For the first go, ask the pupils to guess numbers randomly.
- » Next, using a new number, ask the pupils to guess the number sequentially from one, e.g. 'Is the number one?' and so on. Explain that this is called a linear search. Allow them to have as many goes as needed to guess the number.
- » Finally, using a new number again, explain how to use a binary search. Explain to the learners that they already know the number is less than 100, so suggest they ask, 'Is it less that 50?' then, 'Is it less than 25?' or 'Is it less than 75?' depending on the answer. Tell the pupils to keep halving the section they are searching in until the number is found.
- » Afterwards, talk about which approach found the number quicker. When they are familiar with using a binary search method, replay the game using a number between 1 and 1000.

- Organise the pupils to sort a set of unknown weights into weight order using a simple pan balance, thinking carefully about the algorithm they're following to do this, and then to think of a quicker way to accomplish the same activity. See http://csunplugged.org/sorting-algorithms for a demonstration of this.
- Explain to the pupils that not all algorithms are made of sequences of instructions: some are rule based. Introduce rule-based algorithms by writing a number sequence on the board, e.g. 3, 6, 9, 12 or 2, 4, 8, 16. Ask the pupils to work out the rule for the sequence (adding 3, or doubling the number) and to predict the next number. Explain that the rule for the sequence is the algorithm and the process by which they worked it out was logical reasoning.

www Further resources

- Bagge, P., 'Flow Charts in Primary Computing Science', available at: http://philbagge.blogspot.co.uk/2014/04/flow-charts-in-primary-computing-science.html.
- Barefoot Computing, 'KS2 Logical Number Sequences Activity', available at: http://barefootcas.org.uk/programme-of-study/use-logical-reasoning-explain-simple-algorithms-work/ks2-logical-number-sequences-activity/ (free, but registration required).
- Cormen, T., 'Algorithms Unlocked' (MIT Press, 2013).
- Peyton Jones, S. and Goldberg, A. (Microsoft Research), 'Getting from A to B: Fast Route-Finding Using Slow Computers', available at: www.ukuug.org/events/agm2010/ShortestPath.pdf.
- Slavin, K., 'How Algorithms Shape Our World', available at: www.ted.com/talks/kevin_slavin_how_algorithms_shape_our_world?language=en.
- Steiner, C., 'Automate This: How Algorithms Came to Rule Our World' (Portfolio Penguin, 2013).

Decomposition

How do I solve a problem by breaking it into smaller parts?

The process of breaking down a problem into smaller manageable parts is known as decomposition. Decomposition helps us solve complex problems and manage large projects.

This approach has many advantages. It makes the process a manageable and achievable one – large problems are daunting, but a set of smaller, related tasks are much easier to take on. It also means that the task can be tackled by a team working together, each bringing their own insights, experience and skills to the task.

How is decomposition used in the real world?

Decomposing problems into their smaller parts is not unique to computing: it's pretty standard in engineering, design and project management.

Software development is a complex process, and so being able to break down a large project into its component parts is essential – think of all the different elements that need to be combined to produce a program, like PowerPoint.

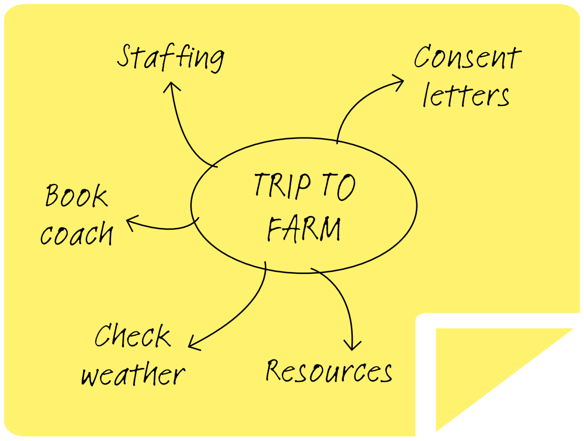
The same is true of computer hardware: a smartphone or a laptop computer is itself composed of many components, often produced independently by specialist manufacturers and assembled to make the finished product, each under the control of the operating system and applications.

A tablet can be broken down (decomposed) into smaller components.
With thanks to iFixit.com

How is decomposition used in school?

You'll have used decomposition to tackle big projects at school, just as programmers do in the software industry.

- Delivering your school's curriculum: typically this would be decomposed as years and subjects, further decomposed into terms, units of work and individual lessons or activities. Notice how the project is tackled by a team working together (your colleagues), and how important it is for the parts to integrate properly.
- Putting on a school play, organising a school trip or arranging a school fair.



A task such as organising a school trip can be decomposed into smaller chunks.

How is decomposition used across the curriculum?

You and your pupils will already use decomposition in many different ways across the curriculum.

- In science or geography, labelling diagrams to show the different parts of a plant, or the different nations which make up the UK.
- In English, planning the different parts of a story.
- In general project planning, planning a research project for any subject or working collaboratively to deliver a group presentation. Technology can help with this sort of collaborative group work, or can even be a focus for it, and great collaborative tools are available in Office 365 and other 'cloud'-based software.
- In maths, breaking down a problem to solve it.

Where does decomposition fit in the new computing curriculum?

The computing curriculum expects that key stage 2 pupils learn to 'solve problems by decomposing them into smaller parts'[3]; it also expects pupils to design and create a range of systems with particular goals in mind (here, system implies something with a number of interconnected components).

As pupils plan their **programs** or systems, encourage them to use decomposition: to work out what the different parts of the program or system must do, and to think about how these are inter-related.
For example, a simple educational game is going to need some way of generating questions, a way to check if the answer is right, some mechanism for recording progress such as a score and some sort of user interface, which in turn might include graphics, animation, interactivity and sound effects.

Plan opportunities for pupils to get some experience of working as a collaborative team on a software development project, and indeed other projects in computing. This could be media work such as animations or videos, shared online content such as a wiki, or a challenging programming project such as making a computer game or even a mobile phone app.

[3] National Curriculum in England, *Computing Programmes of Study* (Department for Education, 2013).

Classroom activity ideas

- Organise for the pupils to tackle a large-scale programming project, such as making a computer game, through decomposition. Even for a relatively simple game the project would typically be decomposed as follows: planning, design, algorithms, coding, animation, graphics, sound, debugging and sharing. A project like this would lend itself to a collaborative, team-based approach, with development planned over a number of weeks.
- Take the case off an old desktop computer and show the pupils how computers are made from systems of smaller components connected together. Depending on the components involved, some of these can be disassembled further still, although it's likely to be better to look at illustrations of the internal architecture of such components.
- Organise for the pupils to carry out a collaborative project online, for example through developing a multi-page wiki site. For example, pupils could take the broad topic of **e-safety**, decompose this into smaller parts and then work collaboratively to develop pages for their wiki, exploring each individual topic. The process of writing these pages can be further decomposed, through planning, research, drafting, reviewing and publishing phases.

Further resources

- Apps for Good, available at: www.appsforgood.org/.
- Barefoot Computing, 'Decomposition', available at: http://barefootcas.org.uk/sample-resources/decomposition/ (free, but registration required).
- Basecamp (professional project management software) can be used by teachers with their class (free), available at: https://basecamp.com/teachers.
- Gadget Teardowns, available at: www.ifixit.com/Teardown.
- NRICH, 'Planning a School Trip', available at: http://nrich.maths.org/6969.
- Project Management Institute Educational Foundation, 'Project Management Toolkit for Youth', available at: http://pmief.org/learning-resources/learning-resources-library/project-management-toolkit-for-youth.

Abstraction

How do you manage complexity?

For American computer scientist Jeanette Wing, credited with coining the term, abstraction lies at the heart of computational thinking:

> *The abstraction process – deciding what details we need to highlight and what details we can ignore – underlies computational thinking.*[4]

Abstraction is about simplifying things; identifying what is important without worrying too much about the detail. Abstraction allows us to manage complexity.

We use abstractions to manage the complexity of life in schools. For example, the school timetable is an abstraction of what happens in a typical week: it captures key information such as who is taught what subject where and by whom, but leaves to one side further layers of complexity, such as the learning objectives and activities planned in any individual lesson.

How is abstraction used across the curriculum?

Abstraction is such a powerful way of thinking about systems and problems that it seems worth introducing pupils to this whilst they're still at primary school. This doesn't have to be just in computing lessons.

- In maths, working with 'word problems' often involves a process of identifying the key information and establishing how to represent the problem in the more abstract language of arithmetic, algebra or geometry.
- In geography, pupils can be helped to see a map as an abstraction of the complexity of the environment, with maps of different scales providing some sense of the layered nature of abstraction in computing.
- In history, pupils are taught world history or national history as an abstraction of the detail present in local histories and individual biographies, which are themselves abstractions of actual events.

[4] 'Computational thinking and thinking about computing' (The Royal Society, 2008).

- In music, the piano score of a pop song might be thought of as an abstraction for that piece of music.

Where does abstraction fit in the new computing curriculum?

The national curriculum for computing leaves abstraction until key stage 3, although it is part of the overarching aims of the subject, which seeks to ensure that all pupils:

> *can understand and apply the fundamental principles and concepts of computer science, including abstraction, logic, algorithms and **data** representation.*[5]

In computing lessons, pupils can learn about the process of abstraction from playing computer games, particularly those that involve interactive simulations of real world systems (see Classroom activity ideas). Encourage pupils' curiosity about how things work, helping them to think about what happens inside the computer or on the internet as they use software or browse the web.

When pupils put together a presentation or video on a topic they know about, they'll need to focus on the key information, and think about how this can be represented, whilst leaving to one side much of the detail of the subject: this too involves abstraction.

Classroom activity ideas

- Encourage pupils who are learning to program to create their own games. If these are based on real world systems then they'll need to use some abstraction to manage the complexity of that system in their game. In a simple table tennis game, e.g. Pong, the **simulation** includes the ball's motion in two dimensions and how it bounces off the bat, but it ignores factors such as air resistance, spin or even gravity. Ask your pupils to think really carefully about what detail they need to include, and what can be left out when programming a similar game.

[5] National Curriculum in England, *Computing Programmes of Study* (Department for Education, 2013).

Further resources

- Barefoot Computing, 'Abstraction', available at: http://barefootcas.org.uk/barefoot-primary-computing-resources/concepts/abstraction/ (free, but registration required).
- BBC Bitesize, 'Abstraction', available at: www.bbc.co.uk/education/guides/zttrcdm/revision.
- BBC Cracking the Code, 'Simulating the Experience of F1 Racing Through Realistic Computer Models', available at: www.bbc.co.uk/programmes/p016612j.
- Google for Education, 'Solving Problems at Google Using Computational Thinking', available at: www.youtube.com/watch?v=SVVB5RQfYxk.
- 'The Art of Abstraction – Computerphile', available at: www.youtube.com/watch?v=p7nGcY73epw.

Patterns and generalisation

How can you make things easier for yourself?

In computing, the method of looking for a general approach to a class of problems is called generalisation. By identifying patterns we can make predictions, create rules and solve more general problems. For example, in learning about area, pupils *could* find the area of a particular rectangle by counting the centimetre squares on the grid on which it's drawn. But a better solution would be to multiply the length by the width: not only is this quicker, it's also a method that will work on *all* rectangles, including really small ones and really large ones. Although it takes a while for pupils to understand this formula, once they do it's so much faster than counting squares.

How are patterns and generalisation used in the national curriculum?

Pupils are likely to encounter the idea of generalising patterns in many areas of the primary curriculum.

- From an early age, they'll become familiar with repeated phrases in nursery rhymes and stories; later on they'll notice repeated narrative structures in traditional tales or other genres.
- In music, children will learn to recognise repeating melodies or bass lines in many musical forms.
- In maths, pupils typically undertake investigations in which they spot patterns and deduce generalised results.
- In English, pupils might notice common rules for spellings, and their exceptions.

Classroom activity ideas

- In computing, encourage pupils to always look for simpler or quicker ways to solve a problem or achieve a result. Ask pupils to explore geometric patterns using turtle graphics commands in languages like Scratch, Logo or TouchDevelop to create 'crystal flowers' (see pages 26–27). Emphasise how the use of repeating blocks of code is much more efficient than writing each command separately, and allow pupils to experiment with how changing one or two of the numbers used in their program can produce different shapes.
- Organise for the pupils to use graphics software to create tessellating patterns to cover the screen. As they do this, ask them to find quicker ways of completing the pattern, typically by copying and pasting groups of individual shapes.
- Help the pupils to create rhythmic and effective music compositions using simple sequencing software in which patterns of beats are repeated.
- Ask the pupils to experiment with number patterns and sequences using Scratch or other programming languages. Can they work out a general program which they could use to generate any linear number sequence?

Further resources

- Barefoot Computing, 'Patterns', available at: http://barefootcas.org.uk/barefoot-primary-computing-resources/concepts/patterns/ (free, but registration required).
- Isle of Tune app, available at: http://isleoftune.com.
- Laurillard, D., *Teaching as a Design Science: Building Pedagogical Patterns for Learning and Technology* (Routledge, 2012).
- Pattern in Islamic art, available at: www.patterninislamicart.com.
- M. C. Escher website, available at: www.mcescher.com.

How does software get written?

As well as the above processes, there are also a number of approaches that characterise computational thinking. If pupils are to start thinking computationally, then it's worth helping them to develop these approaches to their work, so they can be more effective in putting their thoughts into action.

Tinkering

There is often a willingness to experiment and explore in computer scientists' work. Some elements of learning a new programming language or exploring a new system look quite similar to the sort of purposeful play that's seen as such an effective approach to learning in the best nursery and reception classrooms.

Open source software makes it easy to take someone else's code, look at how it's been made and then adapt it to your own particular project or purpose. Platforms such as Scratch and TouchDevelop positively encourage users to look at other programmers' work and use this as a basis for their own creative coding.

In class, encourage pupils to play with a new piece of software, sharing what they discover about it with one another, rather than you explaining exactly how it works. Also, look for ways in which pupils can use others' code, from you, their peers, or online, as a starting point for their own programming projects.

Creating

Programming *is* a creative process. Creative work involves both originality and making something of value: typically something that is useful or at least fit for the purpose intended.

Encourage pupils to approach tasks with a creative spirit, and look for programming tasks that allow some scope for creative expression rather than merely arriving at the right answer.

Encourage pupils to reflect on the quality of the work they produce, critiquing their own and others' projects. The process of always looking for ways to improve on a software project is becoming common practice in software development. Look for projects in which artistic creativity is emphasised, such as working with digital music, images, animation, virtual environments or even 3D printing.

Debugging

Because of its complexity, the code programmers write often doesn't work as it's intended.

Getting pupils to take responsibility for thinking through their algorithms and code, to identify and fix errors is an important part of learning to think, and work, like a programmer. It's also something to encourage across the curriculum: get pupils to check through their working in maths, or to proofread their stories in English. Ask pupils to debug one another's code (or indeed proofread one another's work), looking for mistakes and suggesting improvements. There's evidence that learning from mistakes is a particularly effective approach, and the process of pupils debugging their own or others' code is one way to do this. Keep an eye on the bugs that your pupils do encounter, as these can sometimes reveal particular misconceptions that you may need to address (see pages 28–29).

Persevering

Computer programming *is* hard. This is part of its appeal – writing elegant and effective code is an intellectual challenge requiring not only an understanding of the ideas of the algorithms being coded and the programming language you're working in, but also a willingness to persevere with something that's often quite difficult and sometimes very frustrating. Carol Dweck's work on 'growth mind-sets' suggests that hard work and a willingness to persevere in the face of difficulties can be key factors in educational outcomes. Encourage pupils to look for strategies they can use when they do encounter difficulties with their programming work, such as working out exactly what the problem is, searching for the solution on Bing or Google (with the safe search mode locked), KidRex or Swiggle, or asking a friend for help.

Collaborating

Software is developed by teams of programmers and others working together on a shared project. Look for ways to provide pupils with this experience in computing lessons too. Collaborative group work has long had a place in primary education, and computing should be no different.

Many see 'pair programming' as a particularly effective development method, with two programmers sharing a screen and a keyboard, working together to write software. Typically one programmer acts as the driver, dealing with the detail of the programming, whilst the other takes on a navigator role, looking at the bigger picture. The two programmers regularly swap roles, so both have a grasp of both detail and big picture. Working in a larger group develops a number of additional skills, with each pupil contributing some of their own particular talents to a shared project. However, it's important to remember that all pupils should develop their understanding of each part of the process, so some sharing of roles or peer-tutoring ought normally to be incorporated into such activities.

Further resources

- Barefoot Computing, 'Computational Thinking Approaches', available at: http://barefootcas.org.uk/barefoot-primary-computing-resources/computational-thinking-approaches/ (free, but registration required).
- Briggs, J., 'Programming with Scratch Software: The Benefits for Year Six Learners' (Bath Spa MA dissertation, 2013), available at: https://slp.somerset.gov.uk/cypd/elim/somersetict/Computing_Curriculum_Primary/Planning/MA_JBriggs_Oct2013.pdf.
- DevArt: Art Made with Code, available at: https://devart.withgoogle.com/.
- Dweck, C., 'Mindset: How You Can Fulfil Your Potential' (Robinson, 2012).
- Education Endowment Foundation toolkit, available at: http://educationendowmentfoundation.org.uk/toolkit/.
- Papert, S. and Harel, I., 'Situating Constructionism' (Ablex Publishing Corporation, 1991), available at: www.papert.org/articles/SituatingConstructionism.html.

Programming

Introduction to programming

What is programming?

Programming is the process of designing and writing a set of instructions (a program) for a computer in a language it can understand.

This can be really simple, such as the program to make a robot toy trace out a square; or it can be incredibly sophisticated, such as the software used to forecast the weather or to generate a set of ranked search results.

Programming is a two-step process.

- First, you need to analyse the problem or system and design a solution. This process will use logical reasoning, decomposition, abstraction and **generalisation** (see pages 6–17) to design algorithms to solve the problem or model the system.
- Secondly, you need to express these ideas in a particular programming language on a computer. This is called coding, and we can refer to the set of instructions that make up the program as 'code'.

Programming provides the motivation for learning computer science – there's a great sense of achievement when a computer does just what you ask it, because you've written the precise set of instructions necessary to make something happen. Programming also provides the opportunity to test out ideas and get immediate feedback on whether something works or not.

What should programming be like in schools?

It's possible to teach **computational thinking** without coding and vice versa, but the two seem to work best hand-in-hand.

Teaching computational thinking without giving pupils the opportunity to try out their ideas as code on a computer is like teaching science without doing any experiments. Similarly, teaching coding without helping pupils to understand the underlying processes of computational thinking is like doing experiments in science without any attempt to teach pupils the principles which underpin them.

This is reflected in the new computing curriculum, which states that pupils should not only know the principles of information and computation, but should also be able to put this knowledge to use through programming. One of the aims of the national curriculum for computing is that pupils can analyse problems in computational terms, and have repeated practical experience of writing computer programs in order to solve problems.

In key stage 1, pupils should be taught *how* simple **algorithms** are implemented as programs on digital devices. The phrase 'digital devices' encompasses tablets, laptop computers, **programmable toys**, and perhaps also distant **web servers**. It can be useful for pupils to be able to see their algorithms, in whatever way they've recorded these, and their code side by side.

Children can use simple arrow cards to record algorithms for programmable toys.

Pupils also should have the opportunity to create and **debug** (see pages 28–29) their own **programs**, as well as predicting what a program will do.

In key stage 2, pupils should be taught to design and write programs that accomplish specific goals, which should include controlling or simulating physical systems, for example making and programming a Lego robot. They should be taught to use **sequence**, **selection** and **repetition** in their programs (see pages 24–27), as well as variables to store **data**. They should also learn to use logical reasoning to detect and fix the errors in their programs.

Classroom activity ideas

- There are simple activities on the Barefoot Computing website; see Further Resources below.
- Here are some ideas for extended programming projects:
  - Year 2: solve a maze using a floor/screen turtle
  - Year 3: create a simple animation
  - Year 4: create a question and answer maths game
  - Year 5: create more complex computer games
  - Year 6: develop a simple app for a tablet or smartphone.

Further resources

- Barefoot on ‘Programming’, available at: http://barefootcas.org.uk/barefoot-primary-computing-resources/concepts/programming/ (free, but registration required).
- BBC Bitesize: Controlling physical systems, available at: www.bbc.co.uk/guides/zxjsfg8.
- BBC Cracking the Code, for examples of source code for complex software systems such as robot footballers and a racing car simulator, available at: www.bbc.co.uk/programmes/p01661pj.
- CAS Chair, Prof Simon Peyton Jones’ explanation of some of the computer science that forms the basis for the computing curriculum: http://community.computingatschool.org.uk/resources/2936.
- Code.org for activities and resources, available at: http://code.org/educate.
- Rushkoff, D., *Program or be Programmed: Ten Commands for a Digital Age* (OR Books, 2010).

How do you program a computer?

Programming a computer involves writing code. The code is the set of instructions for the computer written in a programming language that the computer understands. In fact, the programming languages we use are a halfway house – they’re written in a language we can understand which then gets translated by the computer into the ‘machine code’ of instructions that can be run directly on the silicon chips which control it.

Programs comprise precise, unambiguous instructions – there’s no room for interpretation or debate about the meaning of a particular line of computer code. We can only write code using the clearly defined vocabulary and grammar of the programming language, but typically these are words taken from English, so code is something that people can write and understand, but the computer can also follow.

What programming languages should you use?

There are many languages to choose from. The majority are more complex than necessary for those just getting to grips with the ideas of programming, but there are plenty of simple, well supported languages that can be used very effectively in the primary classroom. Try to pick a language that you’ll find easy to learn, or better still, know already.

Consider these points when choosing a programming language:

- Not all languages run on all computer systems.
- Choose a language that is suitable for your pupils. There are computer languages that are readily accessible to primary pupils – in most cases this will mean one that has been written with pupils in mind, or at least adapted to make it easier to learn.
- Choose a language supported by a good range of learning resources. It’s better still if it has online support communities available, both for those who are teaching the language and those who are learning it.
- It is beneficial to the pupils if they can continue working in the language on their home computer, or, even better, if they can easily continue work on the same project via the internet.

There's a view that some languages are better at developing good programming 'habits' than others. Good teaching, in which computational thinking is emphasised alongside coding, should help to prevent pupils developing bad coding habits at this stage.

Which language is right for which key stage?

The table below illustrates a progressive approach to programming languages in a primary setting.

Key stage	Language type	Language	See
Early Years/KS1	Device-specific	Bee-Bot	Page 20
		Roamer-Too	Page 20
KS1	Limited instruction	ScratchJr	Page 22
		Lightbot™	Pages 20–21
KS2	Game programming	Kodu	Pages 21, 22, 25 and 28
	Block-based	Scratch	Pages 21–22, 24–28
	Text-based	Logo	Pages 22, 26–27, 29
		TouchDevelop	Page 23

Whilst there's much to be said for letting pupils explore several programming languages, it's important that they develop a degree of fluency in one, fairly general-purpose language, so that this becomes a medium in which they can solve problems, get useful things done and work creatively.

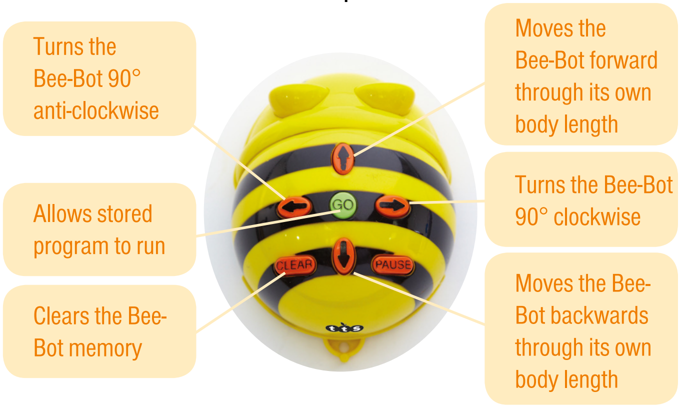
Further resources

- Iry's 'brief, incomplete and mostly wrong history of programming languages': http://james-iry.blogspot.mx/2009/05/brief-incomplete-and-mostly-wrong.html.
- Utting, I., Cooper, S., Kolling, M., Maloney, J. and Resnick, M., (2010) 'Alice, Greenfoot, and Scratch – A Discussion', available at: http://kar.kent.ac.uk/30617/2/2010-11-TOCE-discussion.pdf.
- Wikipedia list of 'Hello, world!' in many programming languages, available at: http://en.wikipedia.org/wiki/List_of_Hello_world_program_examples.

How do you program a floor turtle?

Programming in Early Years and key stage 1 is much more likely to involve working with simple programmable toys than using computers. It's much easier for pupils to learn the idea of programming when working with a really simple language and **interface**, and for them to plan and check their programs when they can, quite literally, put themselves in the place of the device they're programming.

A programmable floor turtle, such as the Bee-Bot or Roamer-Too, is ideal for this. The Bee-Bot programming language consists of five commands: forward, back, turn left, turn right and pause. Programming a Bee-Bot is simply a process of pressing buttons in the desired order to build a sequence of commands, with new commands being added to the end of the sequence.


Turns the Bee-Bot 90° anti-clockwise
Allows stored program to run
Clears the Bee-Bot memory
Moves the Bee-Bot forward through its own body length
Turns the Bee-Bot 90° clockwise
Moves the Bee-Bot backwards through its own body length
GO
CLEAR
PAUSE

This simple device can be used as a basis for many engaging activities, both for early programming and across the curriculum. Younger pupils will often work with the Bee-Bot one instruction at a time, whilst older children will become adept at creating longer sequences of instructions.

A number of tablet or smartphone apps and web-based tools are based on the idea of device-specific languages like these. These are often in the form of a game with a sequence of progressively harder levels in which players create ever more complex sequences of instructions to solve challenges. For example: Bee-Bot, Lightbot™, A.L.E.X and Cargo-Bot.

One approach for scaffolding the transition from floor turtle programming to programming on screen is to use an on-screen **simulation** of a Bee-Bot: it's relatively easy to make (or adapt) one yourself in Scratch 2.0.

Classroom activity ideas

- Allow very young pupils to play with a floor turtle, tinkering with it so they can develop their own sense of the relationship between pressing buttons and running their program.
- Encourage pupils to plan a sequence of instructions for a particular objective, such as getting the floor turtle from one 'flower' to another. Ask pupils to predict what will happen when they run their program, and to explain their thinking (logical reasoning).
- For more complex challenges, provide pupils with the code for a floor turtle's route from one place to another, including an error in the code. Ask the pupils to work out where the bug is in the code and then fix this, before testing out their code on the floor turtle.

Further resources

- BBC on how to program a robot, available at: www.bbc.co.uk/learningzone/clips/programming-robots/4391.html.
- Bee-Bots are available from TTS. Other programmable toys include Roamer-Too (by Valiant) and Pro-Bot (by TTS).
- Barefoot on 'KS1 Bee-Bots, 1, 2, 3 Programming Activity', available at: http://barefootcas.org.uk/barefoot-primary-computing-resources/concepts/programming/ks1-bee-bots-12-3-programming-activity/ (free, but registration required).
- Bee-Bot and Roamer-Too simulator activities, available at: http://scratch.mit.edu/projects/19799927/.
- Lightbot™, available at: http://lightbot.com/.

How do you program things to move around the screen?

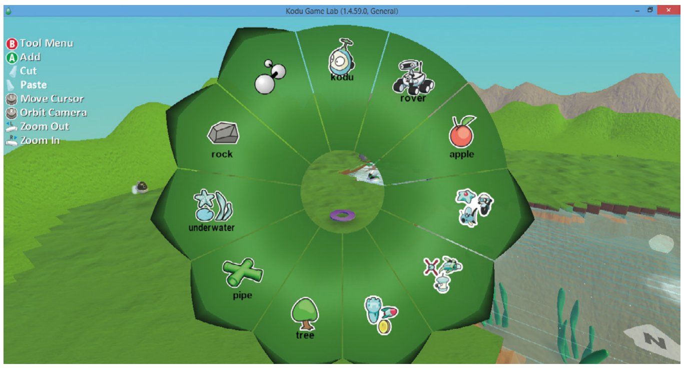
There are a number of graphical programming toolkits available: these make learning to code easier than ever. In most of these, programs are developed by dragging or selecting blocks or icons which represent particular instructions in the programming language. These can normally only fit together in ways that make sense, and the amount of typing, and thus the potential for spelling or punctuation errors, is kept to an absolute minimum.

With toolkits like these it's easy to experiment with creating code. By letting the programmer focus on the ideas of their algorithm rather than the particular vocabulary and grammar of the programming language, learning to program becomes easier and often needs less teacher input.

Kodu

Microsoft's Kodu is a rich, graphical toolkit for developing simple, interactive 3D games.

Each object in the Kodu game world can have its own program. These programs are 'event driven': they are made up of sets of 'when [this happens], do [that]' conditions, so that particular actions are triggered when certain things happen, such as a key being pressed, one object hitting another, or the score reaching a certain level.

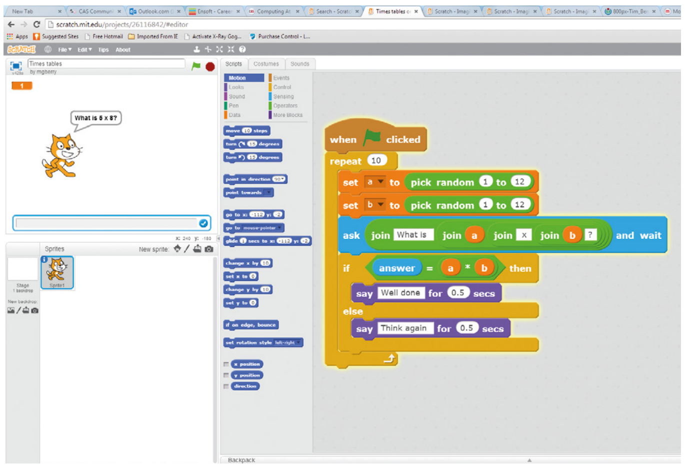


Kodu interface.

Programmers can share their games with others in the Kodu community, which facilitates informal and independent learning. There's also plenty of scope for pupils to download and modify games developed by others, which many find quite an effective way to learn the craft of programming. This can also offer pupils a sense of creating games with an audience and purpose in mind.

Scratch

In MIT's Scratch, the programmer can create their own graphical objects, including the stage background on which the action of a Scratch program happens, and a number of moving objects, or **sprites**, such as the characters in an animation or game.



```
when [flag] clicked
repeat 10
    set a to pick random 1 to 12
    set b to pick random 1 to 12
    ask join What is join a join x join b ? and wait
    if answer = a * b then
        say Well done for 0.5 secs
    else
        say Think again for 0.5 secs
```

Screenshot of a Scratch program.

Each object can have one or more scripts, built up using the building blocks of the Scratch language. To program an object in Scratch, you drag the colour-coded block you want from the different palettes of blocks and snap this into place with other blocks to form a script. Scripts can run in parallel with one another or be triggered by particular events, as in Kodu.

A number of other projects use Scratch as a starting point for their own platforms, for example ScratchJr is an iPad app designed for young programmers (key stage 1) and Berkeley's Snap! allows even more complex programming ideas (such as functions) to be explored through the same sort of building block interface.

There's a great online community for Scratch developers to download and share projects globally, making it easier for pupils to pursue programming in Scratch far beyond what's needed for the national curriculum. There's also a supportive educator community, which has developed and shared high quality curriculum materials.

Scratch is available as a free web-based editor or as a standalone desktop application. Files can be moved between online and offline versions.

Classroom activity ideas

- Pupils could develop a game in Kodu, taking inspiration from some of the games on the Kodu community site. As a starting point, tell them to create a game in which Kodu (the player's avatar in the game) is guided around the landscape bumping into (or shooting) enemies.
- Ask your pupils to create a simple scripted animation in Scratch, perhaps with a couple of programmed characters who take turns to act out a story. Designing the algorithm for a program like this is very similar to storyboarding in video work.

Further resources

- Armoni, M. and Ben-Ari, M., 'Computer science concepts in Scratch', available at: http://stwww.weizmann.ac.il/g-cs/scratch/scratch_en.html.
- Berry, M., 'Scratch across the curriculum', available at: http://milesberry.net/2012/06/scratch-across-the-curriculum/.
- Creative Computing, 'An Introductory Computing Curriculum Using Scratch', available at: http://scratched.gse.harvard.edu/guide/.
- Kelly, J., *Kodu for Kids* (Que Publishing, 2013).
- Kinect2Scratch, to program Microsoft Kinect with Scratch, available at: http://scratch.saorog.com/.
- Kodu Game Lab Community, available at: www.kodugamelab.com/.
- Other graphical programming environments for education include Espresso Coding, 2Code from 2Simple and J2Code.
- Scratch, available at http://scratch.mit.edu/.
- ScratchEd online community for educators, available at: http://scratch.mit.edu/educators/.
- ScratchJr: www.scratchjr.org/.
- Snap!, available at: http://snap.berkeley.edu/.

What is *real* programming?

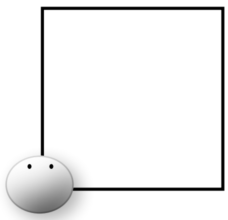
Most software development in academia and industry takes place using text-based languages, where programs are constructed by typing the commands from the programming language at a keyboard.

Historically, text-based programming has been a real barrier for children when learning to code, and there's no need to rush into text-based programming as part of the primary curriculum. It is, however, worth considering text-based programming for an extra-curricular programming club or even in class, if you or your colleagues feel confident with this. Possible text-based programming languages for primary schools could include Logo and TouchDevelop.

Logo

Logo was developed by Seymour Papert and others at MIT as an introductory programming language for children. It's probably best known for its use of 'turtle graphics' – an approach to creating images in which a 'turtle' (either a robot or a representation on screen) is given instructions for drawing a shape, such as:

```
REPEAT 4 [
      FORWARD 100
      RIGHT 90 ]
```



Papert saw Logo as a tool for children to *think* with, just as programming is both the means to and motivation for computational thinking.

In Logo programming, more complex programs are built up by 'teaching' the computer new words. These are called procedures. For example: defining a procedure to draw a square of a certain size using the key words of the language. Once you have defined the procedure 'square', typing it in will then result in the turtle drawing a square. For example:

```
TO SQUARE :SIDE
      REPEAT 4 [
            FORWARD :SIDE
            RIGHT 90 ]
      END
SQUARE 50
```

TouchDevelop

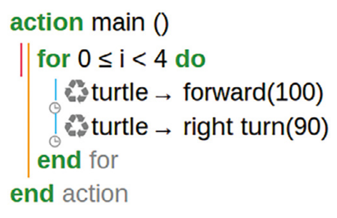
Typing code on a tablet computer or a smartphone is not easy, and this can be problematic for schools that use these devices extensively.

Developed by Microsoft Research, TouchDevelop is a programming language and environment, which takes into account both the challenges posed and the opportunities offered by touch-based interfaces such as those on tablets and smartphones.

TouchDevelop makes it quite easy to develop an app for a smartphone or tablet on the smartphone or tablet itself.

Although TouchDevelop is a text-based language, programmes aren't *typed* but are created by choosing commands from the options displayed in a menu system. In this way, TouchDevelop is a halfway house between graphical and text-based programming.

As with Logo, turtle graphics commands are available as standard. On many platforms TouchDevelop can also access some of the additional **hardware** built into the device, such as the accelerometer or GPS location, allowing more complex apps to be developed: these can be hosted online as web-based apps or installed directly on the device if it's a Windows phone.



```
action main ()
  for 0 ≤ i < 4 do
    turtle → forward(100)
    turtle → right turn(90)
  end for
end action
```

Program to draw a square using a turtle.

A particularly nice feature of TouchDevelop is the use of interactive tutorials to scaffold pupils' learning of the language.

Classroom activity ideas

- Revisit the turtle graphics activities you might have been using for programming in the past.
- Explore how different programming languages can be used to simulate dice being rolled. First, ask pupils to think about how they would do that in Scratch. Then, challenge your pupils to create an app in TouchDevelop which simulates rolling a dice when the phone or tablet is shaken, or when the screen is tapped. Ask pupils to think about how deterministic computers can simulate random events such as these.

Further resources

- Archived lesson plan from DfES for creating crystal flowers: http://webarchive.nationalarchives.gov.uk/20090608182316/http://standards.dfes.gov.uk/pdf/primaryschemes/itx4e.pdf.
- Horspool, N. and Ball, T., *TouchDevelop: Programming on the Go* (APress, 2013), available at: www.touchdevelop.com/docs/book.
- Logo, available at: www.calormen.com/jslogo/ and elsewhere.
- Papert, S., *Mindstorms: Children, Computers, and Powerful Ideas* (Basic Books Inc., 1980), available at: http://dl.acm.org/citation.cfm?id=1095592.
- TouchDevelop interactive tutorials for Hour of Code™: www.touchdevelop.com/hourofcode2.
- TouchDevelop from Microsoft Research: www.touchdevelop.com/.

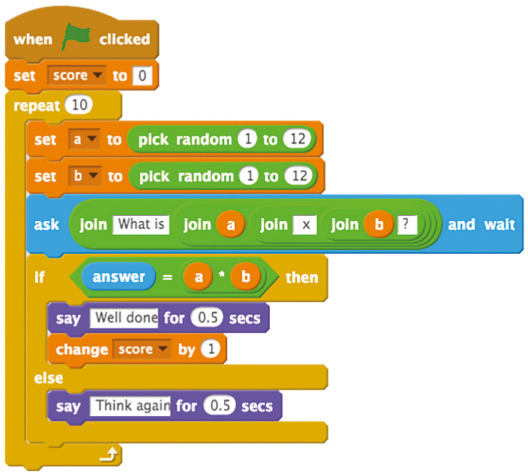
What's inside a program?

Whilst the detail will vary from one language to another, there are some common structures and ideas which programmers use over and over again from one language to another and from one problem to another:

- Sequence: running instructions in order (see below and page 25)
- Selection: running one set of instructions or another, depending on what happens (see pages 25–26)
- Repetition: running some instructions several times (see pages 26–27)
- Variables: a way of storing and retrieving data from the computer's memory (see pages 27–28).

These are so useful that it's important to make sure all pupils learn these.

This Scratch **script** shows sequence, selection, repetition and variables. Can you work out which bit is which before we look at these ideas in detail?



```
when [flag] clicked
set score to 0
repeat 10
    set a to pick random 1 to 12
    set b to pick random 1 to 12
    ask join What is join a join x join b ? and wait
    if answer = a * b then
        say Well done for 0.5 secs
        change score by 1
    else
        say Think again for 0.5 secs
```

Further resources

- BBC Bitesize programming tutorial 'How do we get computers to do what we want?' (covering sequence, selection and repetition), available at: www.bbc.co.uk/guides/z23q7ty.
- Cracking the Code clip, available at: www.bbc.co.uk/programmes/p016j4g5.
- Scratch multiplication test, available at: http://scratch.mit.edu/projects/26116842/#editor.

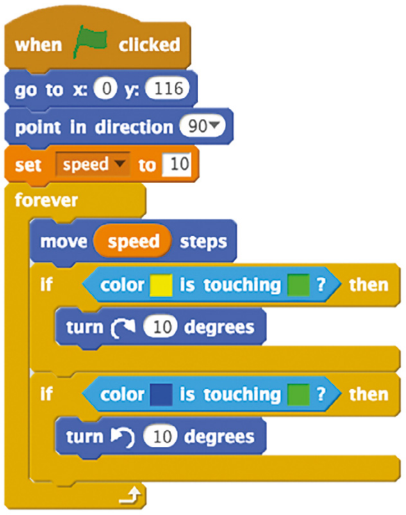
Sequence

Programs are built up of sequences of instructions. When pupils start programming with floor turtles, their programs consist entirely of sequences of instructions, built up as the stored sequence of button presses for what the floor turtle should do. As with any program, these instructions are precise and unambiguous, and the floor turtle will simply take each instruction (the stored button presses) and turn that into signals for the motors driving its wheels.

Initially, pupils might type in just one instruction at a time, clearing the memory after each, but as they become more experienced as programmers, or want to solve a problem more quickly, sequences become more complex.

```
Forward
Forward
Forward
Turn left
Forward
Forward
```

Pupils' first Scratch programs are also likely to be made up of simple sequences of instructions. Again, these need to be precise and unambiguous, and of course the order of the instructions matters. In developing their algorithms, pupils will have to work out exactly what order to put the steps in to complete a task.



```
when [flag] clicked
go to x: 0 y: 116
point in direction 90
set speed to 10
forever
    move speed steps
    if color 🟨 is touching 🟩 ? then
        turn ↻ 10 degrees
    if color 🟦 is touching 🟩 ? then
        turn ↺ 10 degrees
```

A program that children might create in Scratch.

Classroom activity ideas

- Give pupils progressively more complex problems to solve with a floor turtle, asking them first to plan their algorithm for solving these before creating single programs on the floor turtle.
- Provide pupils with existing projects from Scratch (see Further resources on page 26). Allowing them to remix these projects by changing the code and seeing how this affects the program is a useful learning experience.
- Ask pupils to design, plan and code scripted animations in Scratch, perhaps using a timeline or storyboard to work out their algorithm before converting this into instructions for sprites in Scratch.

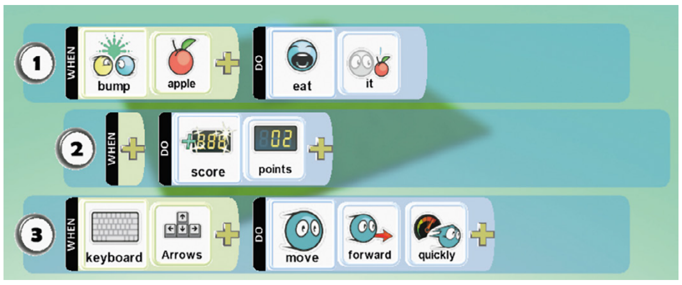
Further resources

- Animation 14: UK Schools Computer Animation Competition (key stage 2), available at: http://animation14.cs.manchester.ac.uk/gallery/winners/KS2/.
- Barefoot on 'Sequence', available at: http://barefootcas.org.uk/barefoot-primary-computing-resources/concepts/programming/sequence/ (free, but registration required).
- Cracking the Code clip on programming a robotic toy car: www.bbc.co.uk/programmes/p01661yg.
- Viking invasion animation in Scratch from Barefoot Computing (for upper KS2), available at: http://barefootcas.org.uk/programme-of-study/use-sequence-in-programs/upper-ks2-viking-raid-animation-activity/ (free, but registration required).

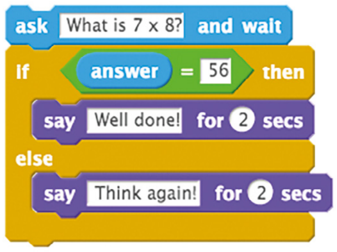
Selection

Selection is the programming structure through which a computer executes one or other set of instructions according to whether a particular condition is met or not. This ability to do different things depending on what happens in the computer as the program is run or out in the real world lies at the heart of what makes programming such a powerful tool.

Selection is an important part of creating a game in Kodu. An object's behaviour in a game is determined by a set of conditions, for example: WHEN the left arrow is pressed, the object will move left. Similarly, interaction with other objects, variables and environments in Kodu are programmed as a set of WHEN … DO … conditions. For example, WHEN I bump the apple DO eat it AND add 2 points to score.


1 WHEN bump apple DO eat it
2 WHEN DO score 02 points
3 WHEN keyboard Arrows DO move forward quickly

In Scratch (and other programming languages) you can build selection into a sequence of instructions, allowing the computer to run different instructions depending on whether a condition is met.

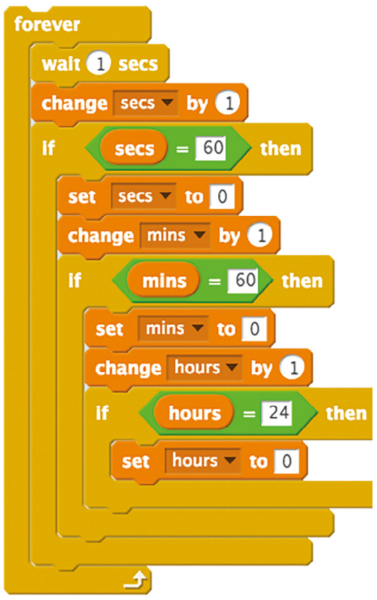


```
ask [What is 7 x 8?] and wait
if <(answer) = [56]> then
    say [Well done!] for (2) secs
else
    say [Think again!] for (2) secs
```

Examples of how selection can be used to start a script in Scratch.

At the core of many educational games is a simple selection command: if the answer is right then give a reward, else say the answer is wrong. See the Scratch script for the times tables game on page 24.

It's also worth noting that selection statements can be nested inside one another. This allows more complex sets of conditions to be used to determine what happens in a program. Look at the way some *if* blocks are inside others in the following script to model a clock in Scratch. The script also uses repetition and three variables for the seconds, minutes and hours of the time:



```
forever
    wait (1) secs
    change [secs] by (1)
    if <(secs) = [60]> then
        set [secs] to [0]
        change [mins] by (1)
        if <(mins) = [60]> then
            set [mins] to [0]
            change [hours] by (1)
            if <(hours) = [24]> then
                set [hours] to [0]
```

Classroom activity ideas

- Encourage pupils to explore the different conditions which the character in Kodu can respond to in its event-driven programming. Get pupils to think creatively about how they might use these when developing a game of their own. Give them time to design their game, thinking carefully about the algorithm, i.e. the rules, they're using.

- Ask pupils to design simple question and answer games in Scratch. Encourage them to first think about the overall algorithm for their game before coding this and then working to develop the user interface, making this more engaging than just a cat asking lots of questions. It's helpful if pupils have a target audience in mind for software like this.

Further resources

- Barefoot Computing on 'Selection', available at: http://barefootcas.org.uk/programme-of-study/use-selection-programs/selection/ (free, but registration required).
- Papert, S., 'Does Easy Do It? Children, Games, and Learning', available at: www.papert.org/articles/Doeseasydoit.html.

Scratch projects to remix

- Analogue clock by mgberry on Scratch, available at: http://scratch.mit.edu/projects/28742256/#editor.
- Addition race by mgberry on Scratch, available at: http://scratch.mit.edu/projects/15905989/#editor.

Repetition

Repetition in programming means to repeat the execution of certain instructions. This can make a long sequence of instructions much shorter, and typically easier to understand.

Using repetition in programming usually involves spotting that some of the instructions you want the computer to follow are the same, or very similar, and therefore draws on the computational thinking process of pattern recognition/generalisation (see pages 15–16). You'll sometimes hear the repeating block of code referred to as a loop, i.e. the computer keeps looping through the commands one at a time as they're executed (carried out).

Think about the Bee-Bot program for a square `(forward, left, forward, left, forward, left, forward, left)`. Notice how for each side we move forward and then turn left. On a Roamer-Too or a Pro-Bot, you could use the repeat command to simplify the coding for this by using the built in repeat command, replacing this code with, for example, `repeat 4 [forward, left]`.

The same would apply in Logo, from which the Roamer-Too and Pro-Bot programming device-specific languages are derived.

Compare:

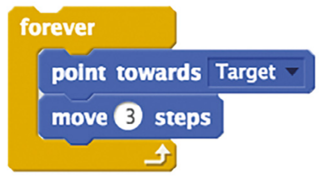
```
FORWARD 100
LEFT 120
FORWARD 100
LEFT 120
FORWARD 100
LEFT 120
```

with:

```
REPEAT 3 [
  FORWARD 100
  LEFT 120 ]
```

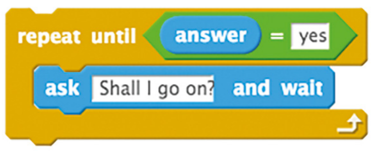
Both programs draw equilateral triangles. Using repetition reduces the amount of typing and makes the program reflect the underlying algorithm more clearly.

In the examples above, the repeated code is run a fixed number of times, which is the best way to introduce the idea. You can also repeat code forever. This can be useful in real world systems, such as a control program for a digital thermostat, which would continually check the temperature of a room, sending a signal to turn the heating on when this dropped below a certain value. This is a common technique in game programming. For example, the following Scratch code would make a sprite continually chase another around the screen:



```
forever
  point towards Target
  move 3 steps
```

Repetition can be combined with selection, so that a repeating block of code is run as many times as necessary until a certain condition is met, as in this fragment in Scratch:

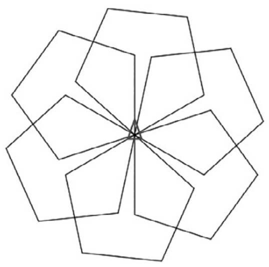


```
repeat until answer = yes
  ask Shall I go on? and wait
```

You can nest one repeating block inside another. The 'crystal flower' programs in Logo use this idea. For example:

```
REPEAT 6 [
      REPEAT 5 [
            FORWARD 100
            LEFT 72 ]
      LEFT 60 ]
```

draws:



Classroom activity ideas

- Ask pupils to use simple repetition commands to produce a 'fish tank' animation in Scratch, with a number of different sprites each running their own set of repeating motion instructions. This can be made more complex by including some selection commands to change the behaviour of sprites as they touch one another.
- Encourage pupils to experiment with 'crystal flower' programs in Scratch, Logo or other languages that support turtle graphics, and investigate the effect of changing the number of times a loop repeats as well as the parameters for the commands inside the loop. There are some great opportunities to link computing with spiritual, social and cultural education.

Further resources

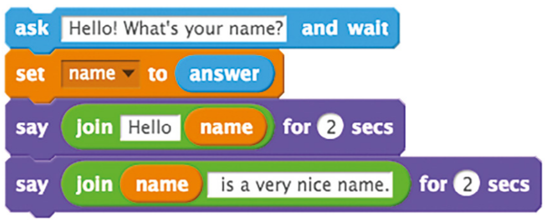
- Barefoot Computing on 'Repetition', available at: http://barefootcas.org.uk/programme-of-study/use-repetition-programs/repetition (free, but registration required).
- Digital Schoolhouse dance scripts, available at: www.resources.digitalschoolhouse.org.uk/key-stage-2-ages-7-10/218-scratch-teaching-dance.
- Scratch 2.0 Fishtank Game tutorial, available at: www.youtube.com/watch?v=-qTZ5bFEdC8.

Variables

Unlike the programming structures of sequence, selection and repetition, a variable is an example of a data structure. It is a simple way of storing one piece of information somewhere in the computer's memory whilst the program is running, and getting that information back later. There's a degree of *abstraction* involved – the actual detail of how the programming language, operating system and hardware manages storing and retrieving data from the memory chips inside the computer isn't important to us as programmers, just as these details aren't important when we're using the clipboard for copying and pasting text. One way of thinking of variables is as labelled shoeboxes, with the difference that the contents don't get removed when they're used.

The concept of a variable is one that many pupils struggle with and it's worth showing them lots of examples to ensure they grasp this. A classic example which pupils are likely to be familiar with, particularly from computer games, is that of score.

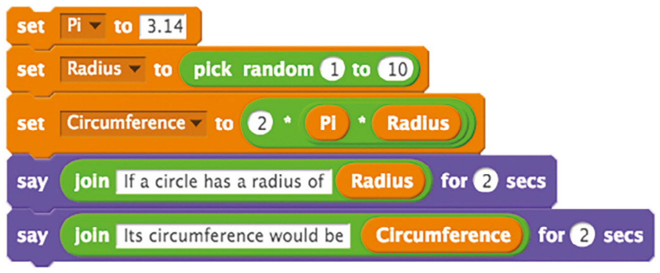
You can use variables to store data input by the person using your program and then refer to this data later on.



```
ask [Hello! What's your name?] and wait
set [name ▾] to (answer)
say (join [Hello] (name)) for (2) secs
say (join (name) [ is a very nice name.]) for (2) secs
```

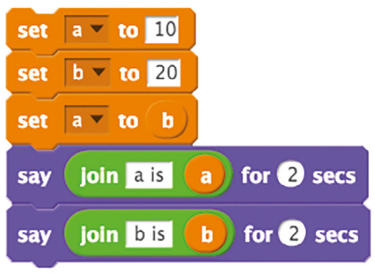
Here, `name` is a variable, in which we store whatever the user types in, and then use it a couple of times in Scratch's response; `answer` is a special temporary variable used by Scratch to store for the time being whatever the user types in. Notice that variables can store text as well as numbers. Other types of data can be stored in variables too, depending on the particular programming language you're working in.

Variables can also be created by the program, perhaps to store a constant value so that we can refer to it by name (`Pi` below), or the result of a computation (`Circumference` in the code below), or random numbers generated by the computer (for example `Radius` below):



```
set [Pi ▾] to [3.14]
set [Radius ▾] to (pick random (1) to (10))
set [Circumference ▾] to ((2) * ((PI) * (Radius)))
say (join [If a circle has a radius of ] (Radius)) for (2) secs
say (join [Its circumference would be ] (Circumference)) for (2) secs
```

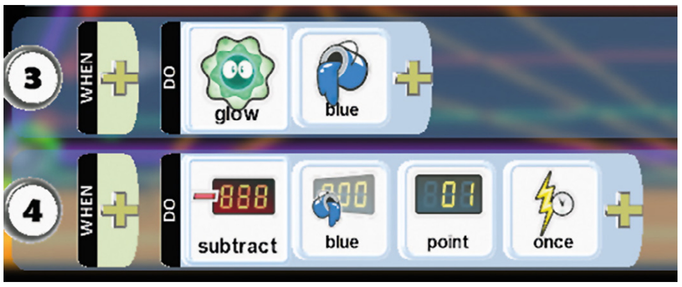
The idea that the contents of the 'box' are still there after the variable is used is sometimes a confusing one for those learning to program. Have a look at the following code and decide what will be displayed on the screen:



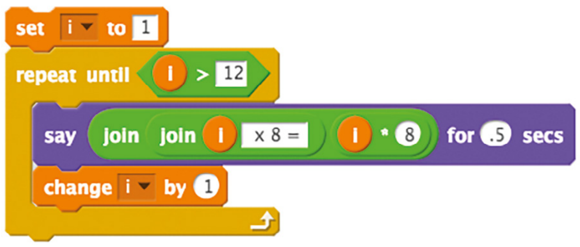
```
set [a ▾] to [10]
set [b ▾] to [20]
set [a ▾] to (b)
say (join [a is] (a)) for (2) secs
say (join [b is] (b)) for (2) secs
```

You should see ‘a is 20’ followed by ‘b is 20’. Try it!

In Kodu and other game programming, variables are useful for keeping track of rewards, such as a score, and for introducing some sort of limit, such as a time limit or health points that reduce each time you’re hit. Kodu’s event-driven approach allows particular actions to be done when variables reach a predetermined level.



One particularly useful example of variables in programming is as an iterator – this is a way of keeping track of how many times you’ve been round a repeating loop and of doing something different each time you do. To do this, we initialise a counter to zero or one at the beginning of the loop and then add one to it each time we go round the loop. For example, the following script would get Scratch to say its eight times table:



```
set i to 1
repeat until (i) > 12
    say join join (i) x 8 = (i) * 8 for .5 secs
    change i by 1
```

You can also use an iterator like this to work with strings (words and sentences) one letter at a time, or through lists of data one item at a time. Take care with the beginning and end, as it’s all too easy to start or end too soon or too late with iterators.

Classroom activity ideas

- Get pupils to create a mystery function machine in Scratch, which accepts an **input**, stores this in a variable and then uses mathematical operators to produce an **output** shown on screen. Setting the display to full screen in Scratch, pupils can challenge one another (and you) to work out what the program does by trying different inputs.
- Pupils can use variables in their games programs, in say Scratch or Kodu, using a score to reward the player for achieving particular objectives (such as collecting apples), and imposing a time limit.

Further resources

- Bagge, P., ‘Text Adventure Game’ for Scratch, available at: http://code-it.co.uk/year4/text_adventure_game.pdf.
- Barefoot Computing on ‘Variables’, available at: http://barefootcas.org.uk/programme-of-study/work-variables/variables/ (free, but registration required).
- BBC Bitesize article ‘How do computer programs use variables?’, available at: www.bbc.co.uk/guides/zw3dwmn.
- Binary search jigsaw and solution by mgberry, available at: http://scratch.mit.edu/projects/20255402/ and http://scratch.mit.edu/projects/28907496/.
- How to program a Scratch 2.0 times table test, available at: www.youtube.com/watch?v=YHGyPfGg1x8.
- Notes and tutorial on variables in Scratch, available at: http://wiki.scratch.mit.edu/wiki/Variable and http://wiki.scratch.mit.edu/wiki/Variables_Tutorial.

Can we fix the code?

Errors in algorithms and code are called ‘bugs’, and the process of finding and fixing these is called ‘debugging’. Debugging can often take much longer than writing the code in the first place. Whilst fixing a program so that it does work can bring a great buzz, staring at code that still won’t work can be the cause of great frustration too: this can be tricky to manage in class.

The national curriculum for key stage 2 expects that pupils will be taught to **use logical reasoning to detect and correct errors in algorithms and programs**, so it’s not really enough for pupils to fix their code without being able to give an explanation for what went wrong and how they fixed this.

In programming classes, pupils focused on the task of writing a program for a particular goal might want help from you or others to fix their programs: tempting as this may be, it’s worth you and they remembering that the objective in class is not to get a working program, but to learn how to program – their ability to debug their own code is a big part of that.

What strategies can you use to support debugging?

One way that you can help is to provide a reasonably robust, general set of debugging strategies which pupils can use for any programming, or indeed more general strategies which they can use when they encounter problems elsewhere.

Debugging should be underpinned by logical reasoning. The Barefoot Computing team suggest a simple sequence of four steps, emphasising the importance of logical reasoning:

1. Predict what should happen.
2. Find out exactly what happens.
3. Work out where something has gone wrong.
4. Fix it.

One way to help predict what should happen is to get pupils to explain their algorithm and code to someone else. In doing so, it's quite likely that they'll spot where there's a problem in the way they're thinking about the problem or in the way they've coded the solution.

In finding out exactly what happens, it can be useful to work through the code, line by line. Seymour Papert described this as 'playing turtle'. So, in a turtle graphics program in Logo (or similar) pupils could act out the role of the turtle, walking and turning as they follow the commands in the language.

In working out where something has gone wrong, encourage pupils to look back at their algorithms before they look at their code. Before they can get started with fixing bugs, they'll need to establish whether it was an issue with their *thinking* or with the way they've implemented that as code.

Some programming environments allow you to step through code one line at a time – you can do this in Scratch by adding (`wait until [space] pressed`) blocks in liberally. Scratch will default to showing where sprites are and the contents of any variables as it runs through code, which can also be useful in helping to work out exactly what caused the problem.

Debugging is a great opportunity for pupils to learn from their mistakes and to get better at programming.

Classroom activity ideas

- Pupils are likely to make many authentic errors in their own code, which they'll want to fix. You might find that it's worth spending some time giving pupils some bugs to find and fix in other programs, both as a way to help develop strategies for debugging and to help with assessment of logical reasoning and programming knowledge. Create some programs with deliberate mistakes in, perhaps using a range of logical or semantic errors, and set pupils the challenge of finding and fixing these.
- Encourage pupils to debug one another's code. One approach is for pupils to work on their own program for the first part of the lesson and then to take over their partner's project, completing this and then debugging this for their friend.
- A similar paired activity is for pupils to write code with deliberate mistakes, setting a challenge to their partner to find and then fix the errors in the code.

Further resources

- Barefoot Computing on 'Debugging', available at: http://barefootcas.org.uk/barefoot-primary-computing-resources/computational-thinking-approaches/debugging/ (free, but registration required).
- BBC Bitesize 'What is debugging?', available at: www.bbc.co.uk/guides/ztkx6sg.
- Debugging challenges from Switched on Computing, available via: http://scratch.mit.edu/studios/306100/.
- Rubber duck debugging, available at: http://en.wikipedia.org/wiki/Rubber_duck_debugging.

Technology

What is a computer?

The term 'computer' originally referred to *people* whose job it was to perform repeated numerical calculations according to a set of instructions (i.e. an algorithm). Since the 1940s it has been used to refer to digital machines that accept data input, process this according to some set of stored instructions (i.e. a program) and output some sort of information.

The power of digital computers comes from their ability to run through these stored instructions incredibly quickly. The silicon chip at the heart of a modern smartphone can execute over a billion instructions per second!

A digital computer comprises two inter-related systems.

- Hardware: the physical components, including the processor, memory, power supply, screen, etc.
- Software: the core **operating system**, embedded control programs, compilers or interpreters and many application programs.

There is an incredible variety of electronic devices that contain some sort of digital computer. There are two different types of device:

Computer-controlled for specific purpose
- digital watch
- digital television
- digital camera ...

Programmable computer – can do many different things
- laptop
- tablet
- smartphone ...

How do computers remember things?

The memory of a computer stores both the programs it needs to operate and the **data** that it processes. There are different types of computer memory and usually there's a trade-off between speed and cost. These days, high capacity storage has become very cheap, so that data centres can provide users with vast amounts of storage for little or no cost through services such as Microsoft OneDrive and Google Drive.

Irrespective of where programs or data are stored in computer memory, they are always stored in a digital format. Information is represented as sequences of numbers. The numbers themselves are stored in a binary code, represented using just two symbols: 0 and 1 (this number system is called base 2). Each 0 or 1 is called a bit.

A range of standard codes are used to convert machine code, images, sound or video into a digital format. These provide standard ways to represent information of different types in binary. Text data is encoded in Unicode. A byte is a group of eight bits; it's used as a unit of memory. Eight bits are more than enough to store one character from the Latin alphabet, in upper or lower case, a punctuation symbol, a digit, etc. One thousand bytes make a kilobyte: enough to store 1000 characters (a short paragraph).

Images, sound and video have their own accepted standards for being encoded digitally, such as bitmaps for images or 'WAV' files for audio. These typically take up much more room than text, so often a form of compression is used (where patterns in the data help reduce the amount of storage space needed). If the original data can be recovered perfectly this is called lossless compression. If some of the original information is thrown away, the original image, sound or video can be stored in a much more compact format, although some of the original quality is lost in the process: this is 'lossy' compression.

Interestingly, the key stage 2 programme of study is more concerned with how information is communicated than how it's stored, but binary representation should be covered in:

- 'work with ... various forms of input and output'
- 'understand **computer networks**, including the internet'.[1]

How do computers interact with the real world?

In order for a computer to be able to do anything in the real world, it needs some form of input (to receive data) and some form of output (to push information back out).

The form of input will vary:

Laptop inputs
- keyboard
- trackpad/touchpad
- microphone
- webcam
- through a port (e.g. USB mouse)
- via a network connection ...

Smartphone inputs
- touch-sensitive screen
- buttons
- microphone
- camera
- GPS receiver
- accelerometer
- barometer
- through a port
- via a network connection ...

A computer will need to convert the analogue, real-world data it receives into a digital format before it can be processed, stored or transmitted. We call this process digitisation and it inevitably involves throwing away some of the fine detail of the real-world information.

[1] National Curriculum in England, *Computing Programmes of Study* (Department for Education, 2013).

Computers can produce many different forms of output:

Laptop/desktop PC outputs
- screen
- speakers
- printer
- headphones
- network connections ...

Smartphone/tablet outputs
- screen
- speakers
- small motor to produce vibrations
- bright LEDs used as a flash
- network connections ...

What is a robot?

A robot is a computer that can move. This could be a single, integrated system such as a **programmable toy**, or it could be a motor under a computer's control, such as a robotic arm in manufacturing.

Robots are used widely in industry, where repetitive tasks can be performed effectively and efficiently by machines. As 'smarter' algorithms have been developed by computer scientists, more and more decision-making capabilities can be built in to the robot, so that it can autonomously react to changes in its environment.

Further resources

- 'Arduino the cat, Breadboard the mouse and Cutter the Elephant': video of a group of girls planning and programming soft toys, available at: http://vimeo.com/4313755.
- Barefoot on 'Computer systems', available at: http://barefootcas.org.uk/barefoot-primary-computing-resources/concepts/computer-systems/ (free, but registration required).
- Barefoot on 'Inputs', available at: http://barefootcas.org.uk/programme-of-study/work-various-forms-input/inputs/ (free, but registration required).
- Barefoot on 'Outputs', available at: http://barefootcas.org.uk/programme-of-study/work-various-forms-output/outputs/ (free, but registration required).
- BBC Cracking the Code: Miniature computers, available at: www.bbc.co.uk/programmes/p01661f7.
- BBC Cracking the Code: Robots, available at: www.bbc.co.uk/programmes/p01661tn.

Computer networks

How the internet works

How do computers communicate?

Connecting computers to form computer networks and the internet (a network of networks) has had a huge impact on our lives.

Think about how limited our use of technology in school would be if we had no access to the local network or the internet. Think about how frustrating it is when we have no data signal for our smartphones or wifi for our laptops.

The internet has made it possible to communicate and collaborate with a richness and immediacy never experienced before. And yet, it's something that most of us take for granted.

The new computing curriculum sets out to change this. It requires that pupils are taught:

- in key stage 1: to 'recognise common uses of information technology beyond school'
- in key stage 2: to 'understand computer networks, including the internet [and] how they can provide multiple services, such as the world wide web'
- in key stage 2: to 'use search technologies effectively, appreciate how results are selected and ranked, and be discerning in evaluating digital content'.[1]

How does the internet work?

The internet is a physical thing: it's the cables, fibre, transmitters, receivers, switches, **routers** (and all the rest of the **hardware**) that connects computers, or networks of computers, to one another.

The internet has been designed to do one job: to transport **data** from one computer to another. This information might be an email, the content of a web page, or the audio and video for a video call.

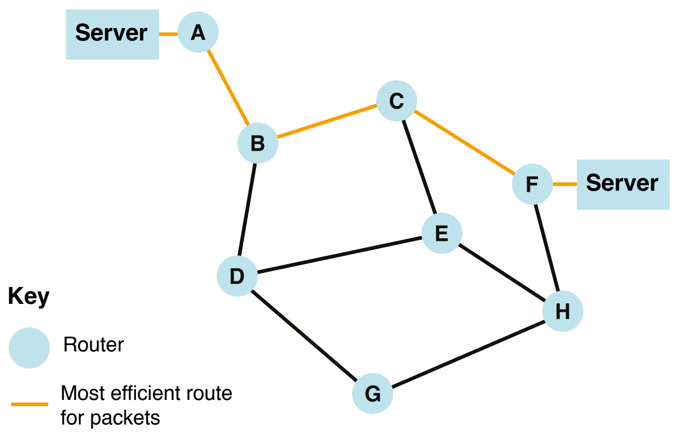
The data that travels via the internet is digital: this means it is expressed as numbers. All information on the internet is expressed this way, including text, images and audio. These numbers are communicated using binary code, which is made up of 1s and 0s, using on/off (or low and high) electrical or optical signals. Binary code is similar to the Morse code used for the telegraph in Victorian times, but it's much, much faster. A good telegraph operator could work at maybe 70 characters (letters) a second, but even a basic school network can pass data at 100 million on/off pulses a second, enough for some 12.5 million characters per second. One transatlantic fibre connection has the capacity for up to 400 billion characters per second!

Digitised information needs to be broken down into small chunks by the computer before it can be sent efficiently. These smaller chunks of data are known as 'packets'.

The small **packets** can be passed quickly through the internet to the receiving computer where they are re-assembled into the original data. The process happens so quickly that high definition video can be watched this way, normally without any glitches.

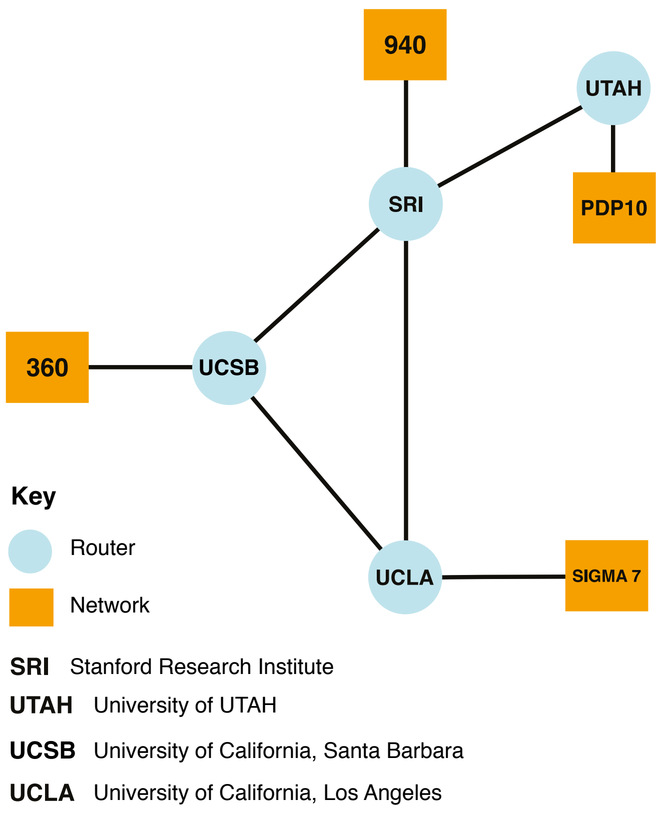
[1] National Curriculum in England, *Computing Programmes of Study* (Department for Education, 2013).

The packets don't all have to travel the same way through the internet: they can take any route from sender to recipient. However, there is generally a most efficient route, which all the packets would take.



A sample network: note there is more than one route for packets to travel.

It's perhaps easier to understand how the internet works now by looking at a picture of how it worked in 1969 when it started:


940
UTAH
SRI
PDP10
360
UCSB
Key
Router
Network
UCLA
SIGMA 7
SRI Stanford Research Institute
UTAH University of UTAH
UCSB University of California, Santa Barbara
UCLA University of California, Los Angeles

Here you see the internet made up of just four routers: UCLA, SRI, UCSB and UTAH. Each router is a piece of hardware that passes packets of data from the networks they are connected to (in the case of UTAH, PDP10, in the case of UCLA, SIGMA 7) to any of the other three networks.

So if you were using the PDP10 network at the University of UTAH and sent a message to someone at UCLA, your message would be passed first to your router at UTAH, then on to the router at Stanford Research Institute (SRI), then (normally) to UCLA's router, where it would be passed on to whichever recipient it was intended for on their SIGMA 7.

The internet is obviously much, much bigger than this example. In real life, the journey of a packet of data from your home computer to one of Microsoft's server farms might look something like this:

your home wifi access point

↓

your home switch and router
(usually all in the same black box)

↓

switches in your nearest BT green cabinet

↓

more switches in your local telephone exchange

↓

London internet exchange

↓

routers near Porthcurno in Cornwall

↓

fibre optics under the Atlantic

↓

further switches and routers in the USA
until Microsoft's internet connection at whichever
of its data centres you are communicating with

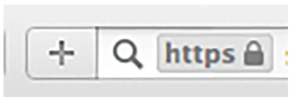
When you type a URL (such as www.bbc.co.uk or www.computingatschool.org.uk) into your browser you send a packet of data requesting the content of these pages to be returned to you. But before this can happen, the domain name first needs to be converted into numbers. This is the job of the **Domain Name Service (DNS)**, which converts these familiar web addresses into numbers known as **IP (Internet Protocol) addresses**. The DNS itself uses the internet to look up (in the equivalent of huge phone books) the numeric address corresponding to the domain names.

Each packet has a destination IP address on it. With it the router can easily look up which way to pass the packet on.

Who can see the data we transmit?

There's nothing to stop routers from looking at the data in the packet before they pass it on (just as there was nothing to stop telegraph clerks reading the messages they passed on in Morse code).

To be able to send information, such as passwords or bank account details, secretly via the internet, it's important to **encrypt** the data first. This happens automatically when using the 'https' version of websites (see page 37). In these situations, you'll see a little green padlock displayed in your browser's address bar. The data is decrypted when it reaches its destination.



Classroom activity ideas

- Ask pupils to draw a picture of the internet. This will allow you to spot any misconceptions they have, and provide an opportunity for pupils to share their understanding.
- Carry out this 'unplugged' activity to model how the internet passes packets of data.
  - » Organise all but four of your pupils into groups.
  - » Tell the pupils to choose one pupil in their group to be the 'group router'. The rest of the group will be 'computers'.
  - » Ask the remaining four pupils to take on the role of 'internet routers', which connect the group routers together.
  - » Give each 'computer' a numerical address, comprising a group number and a computer number (e.g. 1.1, 1.2, 1.3; 2.1, 2.2, 2.3, etc.).
  - » Ask each 'computer' to write a short message to another 'computer' in a different group, splitting their message over three different slips of paper and marking their slips '1 of 3', '2 of 3' and '3 of 3'. Tell them to write their numerical address and the numerical address of the recipient, e.g. 'To: 2.2; From 3.4; 2 of 3.' This is the 'packet header'.
  - » Ask the 'computers' to pass their slips to their 'group router', who can pass these on one at a time to the 'internet routers'. They in turn pass them to the correct 'group router' who passes them to the recipient themselves, who can reassemble the message as their other packets arrive.

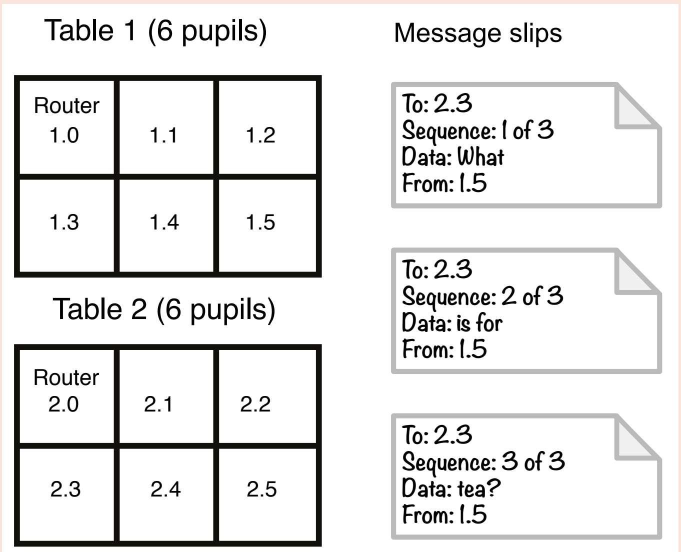


Table 1 (6 pupils)
Router 1.0
1.1
1.2
1.3
1.4
1.5
Table 2 (6 pupils)
Router 2.0
2.1
2.2
2.3
2.4
2.5
Message slips
To: 2.3 Sequence: 1 of 3 Data: What From: 1.5
To: 2.3 Sequence: 2 of 3 Data: is for From: 1.5
To: 2.3 Sequence: 3 of 3 Data: tea? From: 1.5

Role-playing a computer network in class.

- Investigate the physical infrastructure of the school network. Tell the pupils to walk from their laptop to the local wifi point, or to follow the network cable from the computer to the classroom switch. Next, walk together to the school's main network switch, firewall and router. If you can, then walk down to the nearest BT green cabinet, and perhaps to your local telephone exchange, depending on how close this is to you.
- Explore the steps on the journey of a packet using the 'tracert' command at the Windows command prompt, if you have access to this. Also see the Visual traceroute reference in Further resources.
- Ask your school network manager to talk pupils through how the school network connects their computers to the rest of the internet.

Further resources

- Bagge, P., 'Year 5 Computer Science Planning', available at: www.code-it.co.uk/year5/index.htm.
- Barefoot on 'KS2 Modelling the Internet activity', available at: http://barefootcas.org.uk/programme-of-study/understand-computer-networks-including-internet/ks2-activity-modelling-the-internet/ (free, but registration required).
- Barefoot on 'Internet Services', available at: http://barefootcas.org.uk/programme-of-study/multiple-services-provided-networks-internet/internet-services/ (free, but registration required).
- BBC Bitesize clip 'Computer networks – LAN and WAN', available at: www.bbc.co.uk/learningzone/clips/computer-networks-lan-and-wan/4381.html.
- Blum, A., *Tubes: Behind the Scenes at the Internet* (Viking, 2012).

- Andrew Blum's talk 'Discover the physical side of the internet', available at: www.ted.com/talks/andrew_blum_what_is_the_Internet_really.
- Artistic representations of what the internet means, available at: www.canyoudrawtheinternet.com.
- Mark Dorling and others' Digital Schoolhouse planning on networks, 'Networks Unplugged', available at: www.digitalschoolhouse.org.uk/documents/networks-unplugged-workshop-pack.
- Naughton, J., *From Gutenberg to Zuckerberg: What You Really Need to Know About the Internet* (Quercus, 2012).
- Visual traceroute to find the path from their web server to an internet address, available at: www.yougetsignal.com/tools/visual-tracert/.

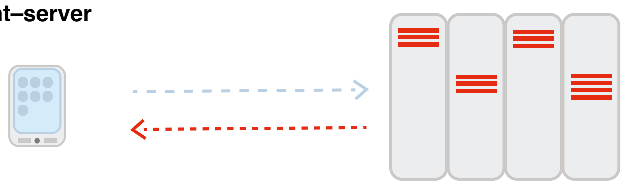
What can you do with the internet?

Picture the train network, efficiently routing trains of all kinds from one point to another, irrespective of what those trains contain. Some will have passengers, others freight, others are perhaps maintenance stock. In the same way, the infrastructure of the internet can be used for lots of different things.

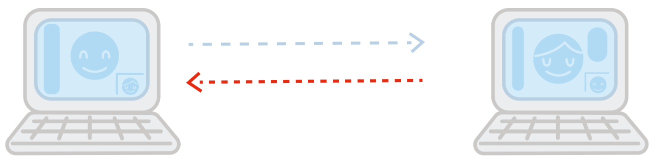
The services which run on computer networks, including the internet, fall into roughly two groups:

1. client–server: one computer (the client) accesses services or content running or stored on another, typically larger, computer (the server)
2. peer-to-peer: two computers communicate directly as equals, passing data directly to and from each other.

Client–server



Peer-to-peer



The World Wide Web (see page 36) fits into the client–server model, but so do lots of other services which use computer networks and the internet as a means of communicating.

A school network will often have one or more computers acting as servers, responding to requests from the desktop, laptop and tablet computers which act as clients. On a local area network (LAN) like this, the servers might provide: central storage and backup for files, access to documents, etc. from any computer on the network, a management information system (such as SIMS), local email accounts, access to printers, username and password authentication, filtering and logging of access to the web and even locally stored copies of frequently visited web pages.

Email is a good example of a client–server system using the internet (although many people's experience of email is as webmail accessed through a browser like Internet Explorer). The journey of an email might be something like this:

- Alice opens up Outlook and starts typing in her email to Bob. She includes Bob's email address, bob@builders.com, in the 'To' line of the email and clicks 'send'.
- The email is transmitted via the internet (or the local network) to her outgoing mail server. If the email is intended for another domain (builders.com here) rather than Alice's own (lookingglass.org) then Exchange will forward the email as packets of data via the internet, which routes these through to the incoming mail server for builders.com as discussed above.
- The inbound mail server at builders.com (again perhaps running Exchange) re-assembles the message from the packets of data, accepts this and stores this ready for Bob to collect.
- Later on, Bob's email client (perhaps also Outlook) connects to his mail server and asks if there are any messages for him. The one from Alice gets transmitted to Bob's computer via the local network or the internet, where Bob can read it in his email software.

Although it might look to Alice and Bob as though they are communicating directly with each other, all their emails are going via the outbound and inbound mail servers. Notice that the contents of their emails aren't encrypted, so the organisations running the two mail servers can read the contents of these messages if they wish.

Not all communication on the internet uses a client–server model. For example, peer-to-peer communication is a model used for Skype and a number of other video conferencing or voice over internet systems. Although Skype uses a server to maintain a list of logged-in users and the IP address of their computers, when a call is connected the packets of data that make up the digitised video and audio for the call are routed directly through the internet between the two parties.

Some online gaming websites use a similar peer-to-peer system, as does BitTorrent, a protocol which allows large files to be shared between many computers by allowing direct peer-to-peer connections. Because peer-to-peer connections are harder for large organisations to monitor, they are favoured by those using the internet for criminal purposes, for example the use of the BitTorrent protocol for illegally sharing copyrighted material.

Classroom activity ideas

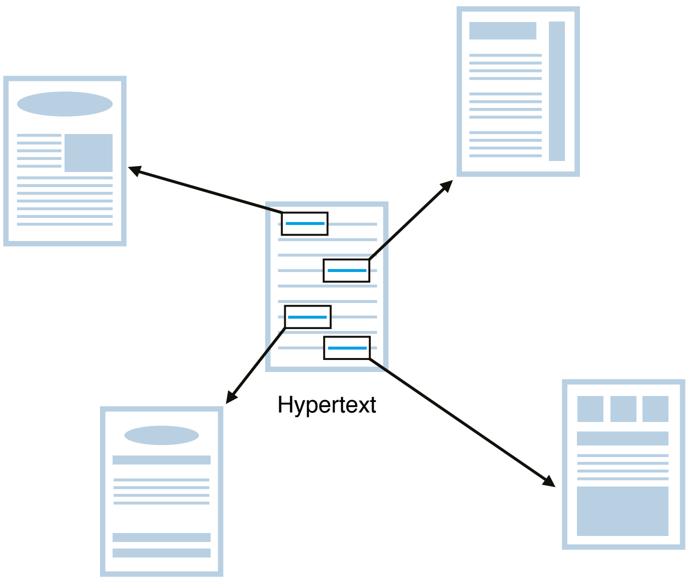
- Role-play can be used very effectively to teach how email works and issues with email security. Explain to pupils that email addresses can be 'spoofed' or accounts hacked. So, not all emails are from who they appear to be. Warn them that files attached to emails can contain viruses. Also explain that links in emails can sometimes point to websites that are set up to capture personal information such as passwords. You might like to run this as part of a larger topic looking at the effective and safe use of email, perhaps in a twinning project with a class in this or another country.
- Share and write a range of emails and written letters. Discuss the advantages and disadvantages of each type of communication.
- Use a video conferencing system to allow experts to talk to the class or to allow two classes to communicate. As you set up the computer, talk through the technical aspects of the call with your pupils. Note: Skype and most other video conferencing systems don't allow children to register for accounts, so you will need to run this as a whole-class activity.
- Encourage pupils to talk about how they and their families use the internet to communicate, highlighting any services they use in addition to the World Wide Web.

Further resources

- Guha, S., Daswani, N. and Jain, R., 'An Experimental Study of the Skype Peer-to-Peer VoIP System' (2006), available at: http://saikat.guha.cc/pub/iptps06-skype.pdf.
- The journey of a letter, available at: www.anpost.ie/anpost/schoolbag/primary/our+people/the+journey+of+your+mail/.
- 'Story of Send on Google Green' (a short cartoon about the journey of a gmail), available at: www.youtube.com/watch?v=5Be2YnlRIg8.

What is the World Wide Web?

In 1989, British computer scientist Tim Berners-Lee decided to combine the capabilities of the internet with the functions of hypertext (documents that include hyperlinks that allow connections to be made between different files) to manage information systems at CERN where he was working.

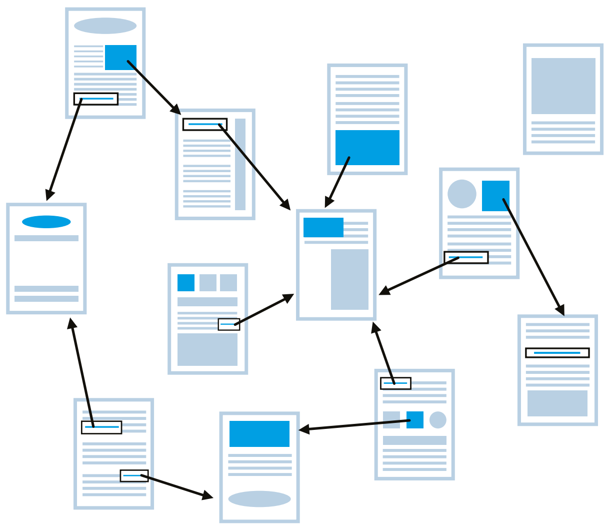


The links in the hypertext take the reader to different documents which extend or support the information in the original document.

Berners-Lee developed a specification for how an internet-based version of hypertext would work and then wrote the software for the first **web servers** and web browsers. The result was the **World Wide Web**.

The internet is about connecting computers together, but the World Wide Web is about the connections between documents. When you click on a web link, another web page is requested from (typically) a different web server somewhere else on the internet.

The content of this web page is then delivered to your web browser.



The World Wide Web is about the connection (the links) between documents.

What standards does the World Wide Web use?

To ensure that all computers could communicate with one another, Berners-Lee developed a set of standards (called protocols) for the Web. Versions of these are all still used today.

1. HTTP (HyperText Transfer Protocol)

This is the process that computers use to request and transfer hypertext to one another.

The Web is a client–server system: we use a web browser on our computer to request a web page from one of the many, many web servers connected to the internet. The request travels as a packet of data via switches and routers until it reaches the intended web server. The server responds by sending back the content of the page, together with any images and formatting instructions and mini programs (typically in JavaScript) needed for the page. If the page isn't there, it sends back a '404: Not found' error message – sometimes you'll see other error messages too.

Remember that the internet doesn't encrypt packets of data: there's another version of HTTP, called HTTPS, where the request for a page, the contents of the page and any information entered into a form (such as a password) are sent over the internet in an encrypted form. This encryption can sometimes be bypassed by network managers and government agencies.

2. URL (Uniform Resource Locator)

URLs are the precise location on the Web where web pages or their components are stored. It's what you type in to your browser's address bar to request a page.

Each bit of a URL means something. Let's look at the URL of one of the first web pages – Berners-Lee's home page for the World Wide Web project itself – to work out what each bit means:

http://info.cern.ch/hypertext/WWW/TheProject.html

- **http:** this is the protocol we're using to request hypertext and the content that comes back – see above.
- **://** is just punctuation – Berners-Lee now thinks it would have been better if he'd skipped the // bit!
- **info** is the name of the web server we're connecting to. Often this will be www these days, or this is just omitted as the main web server for the organisation will be assumed.
- **cern** is the name of the organisation, in this case the European Centre for Nuclear Research.
- **ch** is an abbreviation for the country where the organisation has registered their domain name, in this case Switzerland. Some countries also show what sort of organisation it is registered as, e.g .co.uk for a commercial site and .sch.uk for a school site in the UK. If no country is shown, then it will be registered in the USA: .com for commercial sites, .edu for university sites, and so on.
- **/hypertext** is a directory (folder) on the web server.
- **/WWW** is a directory inside the /hypertext directory on the web server.
- **TheProject** is the name of the actual file we're requesting, in this case a web page about the World Wide Web project. Sometimes you don't see a file name at the end of a URL, in which case the web server will send back the default file for the directory, often an index page such as index.html.
- **.html** is the file extension, which shows what format the page is written in, in this case **HTML** (see page 38). This is like .doc or .docx for a Word file, or .jpg or .jpeg for an image.

Although it is often convenient to use search engines like Google or Bing to find pages rather than typing in URLs, the URL is a good way to check that you're connecting to the web server you think you are (rather than a spoof website). URLs are also useful when acknowledging sources of information, and for creating links between pages (and so building more of the connections that make the Web so useful).

3. HTML (HyperText Mark-up Language)

HTML is the computer language (code) in which the content and structure of a web page are described or 'marked up'.

The content of web pages is stored in HTML format on web servers. Creating a web page involves writing (or getting a computer to generate) the HTML that describes the page. HTML can be read, and written, by humans as well as computers. You can view the HTML source code for any web page using tools built into your web browser. (There's a menu command to do this, or you can press 'ctrl-u' in Internet Explorer.)

These days, the HTML for a web page might not be stored as a file on the web server: in content management systems, when a page is requested it will be generated automatically using a database of content, a template and some programs running on the web server. For example, every time you visit www.bbc.co.uk/newsround/ the page will be generated using the latest news in the database.

More recently, a couple of other languages have come to play an important part in developing for the Web.

CSS (Cascading Style Sheets)

CSS provides formatting information alongside the content and structure of HTML, allowing designers and developers to specify exactly how the content of the page should be displayed in the web browser on a computer, tablet, smartphone or printer.

JavaScript

JavaScript is a programming language that can be interpreted by the web browser itself, allowing interaction with the content of a page to be handled by the user's computer (the client) rather than on the server itself. The web-based version of Office 365 relies heavily on JavaScript.

What's the most amazing thing about the Web?

The amazing thing about the Web isn't really these technologies though. It's that, from its early days as the preserve of academic scientists, so many organisations and individuals have connected their own web servers to the internet and added their own content to the Web. In part this was because Berners-Lee created a system that was accessible, scalable and extensible, capturing the imagination of many. But it's also because he and CERN gave it to the world for free – the standards and the technology were entirely open, without any central authority or commercial company licensing or charging for their use.

Classroom activity ideas

- The national curriculum for history suggests that key stage 1 pupils could look at William Caxton (who introduced the printing press to England in the fifteenth century) and Tim Berners-Lee as examples of 'the lives of significant individuals in the past who have contributed to national and international achievements'. Compare the life, work and influence of these two figures.
- Encourage pupils to look at the different parts of the URLs for the web pages they visit, asking them to explain what each part of the URL means. Make a display showing the different parts of some interesting or common URLs.
- Ask pupils to talk to their parents, grandparents or carers about the difference the World Wide Web has made in their lives.
- Tell pupils to keep a diary of the different ways they use the Web over a week.

Further resources

- BBC Bitesize 'What is the world wide web?', available at: http://www.bbc.co.uk/guides/z2nbgk7.
- Tim Berners-Lee 'Answers for Young People', available at: www.w3.org/People/Berners-Lee/Kids.html.
- The original CERN home page for the Web, available at: http://info.cern.ch/hypertext/WWW/TheProject.html.
- Codecademy curriculum materials, available at: www.codecademy.com/schools/curriculum (registration required).
- Mozilla Web Literacy whitepaper, available at: http://mozilla.github.io/webmaker-whitepaper/.
- Wayback Machine to search for historic web pages, available at: http://archive.org/web/.

How do you make a web page?

There are plenty of tools available for you and your pupils to create your own content for the Web.

Your school's learning platform or VLE provides one way to get content online, as do blogging platforms like WordPress. These platforms usually include a ‘WYSIWYG’ (what you see is what you get) editor. This makes writing content for the Web similar to using Microsoft Word, with a range of formatting controls built in. In most of these editors, you can swap into code (or source view), seeing and editing the HTML itself. This can be a good introduction to working directly in HTML, as you can always swap back to the WYSIWYG view to see the effects of editing the code.

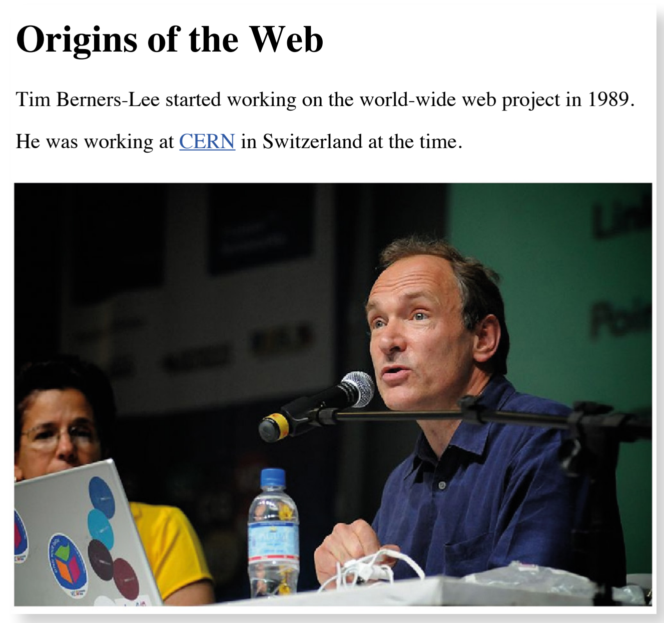
Giving pupils some experience of writing content for the Web through editing HTML ‘by hand’ is well worth doing although it isn’t, strictly speaking, programming. It adds to their understanding of networks including the internet that the national curriculum at key stage 2 expects, and is one more way of using software on a range of devices to create content. It is also a good way to get pupils used to working in a formal, text-based computer language. As with other text-based languages, working in HTML helps reinforce the importance of spelling, punctuation and grammar: mistakes in the mark-up of the page usually become quite apparent in the way the browser displays the page.

Many pupils are likely to find these skills useful in the long term too, both at secondary school and beyond: developing content for the Web is part of many jobs, teaching included.

What does HTML look like?

Let’s compare the HTML code for a simple web page and the page itself.

```
<!doctype html>
<html>
  <head>
      <meta charset=“utf-8”>
    <title>A simple webpage</title>
  </head>
  <body>
    <h1>Origins of the Web</h1>
    <p>Tim Berners-Lee started working on
the world-wide web project in 1989.</p>
    <p>He was working at <a href=“http://
home.web.cern.ch/”>CERN</a> in Switzerland
at the time.</p>
    <img src=“http://upload.wikimedia.org/
wikipedia/commons/thumb/7/7e/Tim_Berners-
Lee_CP_2.jpg/320px-Tim_Berners-Lee_CP_2.
jpg”>
  </body>
</html>
```



Origins of the Web

Tim Berners-Lee started working on the world-wide web project in 1989.

He was working at CERN in Switzerland at the time.

Can you see where the content for the page comes from in the code? Can you see what effect some of the HTML tags (the bits in the `<...>` angle brackets like `<h1>` and `<p>`) have on how the content is structured?

Notice how most of the tags come in matched pairs, e.g.

- `<html>` and ending `</html>` for the whole page
- `<head>` to `</head>` for the information about the page, such as its character set and title
- `<body>` to `</body>` for the content of the page
- `<h1>` to `</h1>` around the main heading for the page
- `<p>` to `</p>` around each paragraph.

Compare the underlined link in the web page with the corresponding code. In the code, `<a>` to `</a>` show where the link should be and `href=“http://home.web.cern.ch/”` inside the `<a>` tag detail where the link should point to.

An image is inserted from elsewhere on the web, using a single `<img>` tag, this time without a matched closing tag, and again giving the location of the image using `src=“http://upload.wikimedia.org/wikipedia/commons/thumb/7/7e/Tim_Berners-Lee_CP_2.jpg/320px-Tim_Berners-Lee_CP_2.jpg”` inside the `<img>` tag.

How do I get started with HTML?

Mozilla’s Thimble tool for creating websites (available at: https://thimble.webmaker.org/) makes it easy to get started with coding in HTML, as it displays the source code alongside the resulting web page.

Rather than starting from a blank page, pupils can try editing other web pages, exploring the structure and HTML code of these pages and seeing what effect changing the code has on how the page is displayed in the browser.

On Internet Explorer, you can use the Developer Tools (hit F12, or launch via the menu) to view and edit the source code (the HTML code which describes the content and structure) for a page. Alternatively, you can install Mozilla's X-Ray Goggles as an active bookmarklet (see Further resources) to remix and share edited web pages.

Classroom activity ideas

- When using their learning platform, VLE or class blog, encourage pupils to swap from the normal WYSIWYG (what you see is what you get) mode of the built-in editor into the code, source or HTML mode and try writing their post or page in that. Remind them that they can swap back and forth to see how the code relates to the page that's displayed. Give pupils a list of some common HTML tags to try out for themselves.
- Set pupils the challenge of making a parody of a web page by using either the Developer Tools in Internet Explorer or X-Ray Goggles to edit the code for the page. It's wise to decide some ground rules for this activity in advance. Show pupils how easily a spoof page can be created this way, and explain why it's so important to check the address of the page they're visiting to confirm it is authentic rather than merely one which looks convincing.
- Rather than asking pupils to write up a story or a report using Word, challenge them to do this using HTML code to make a web page. Emphasise that they need to concentrate on the content and structure of their page, which is what HTML is designed for. Encourage them to add in links to supporting material using the `<a>` tag if they're creating a non-fiction account, and perhaps to add in some images from elsewhere on the Web using the `<img>` tag.

Further resources

- Learn to code tutorials from Codecademy, available at: www.codecademy.com/ (registration required).
- Shay Howe 'Learn to Code and CSS' tutorials, available at: http://learn.shayhowe.com/.
- 'App Design Basics: Learn to code using HTML and CSS' from Playto, available at: https://learn.playto.io/html-css/lesson/0.
- Thimble: https://thimble.webmaker.org/.
- Tutorials on a wide range of computer languages from w3schools, available at: www.w3schools.com/.
- See the source code behind web pages using X-Ray Goggles, available at: https://goggles.webmaker.org/.

How does a search engine work?

Search engines like Google and Bing have transformed the way we use the Web. Instead of having to remember URLs for the pages we want, or following the links from one page to another, we can normally rely on these web-based programs to give us the most relevant results for our query.

Given how much we use search engines, it's important to use them effectively and efficiently, to show some discernment in deciding how far a particular page can be trusted, and to have some grasp of the **algorithms** that underpin them.

In order for Bing or Google to be able to respond to a search query, they use their index of the Web. A search engine builds its index by using specially written programs called 'web crawlers'. The web crawlers create a huge copy of the publicly accessible bits of the Web (called a cache) which is stored on the search engine's servers.

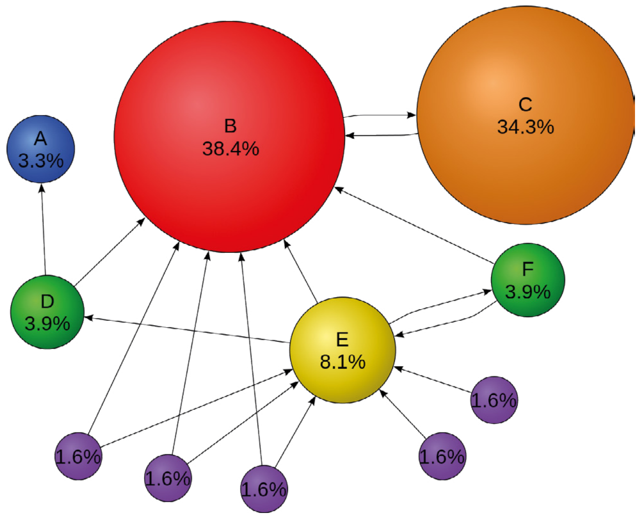
When a new or updated copy of a web page is added to the cache, an entry for the page will be added to, or updated in, the search engine's index of the Web for each of the words on the page (typically ignoring small, common words like 'and', 'the' and so on). The web crawlers continue to build and update the cache by following all the hyperlinks in the page, requesting and making copies of those pages too, adding or updating index entries for them, and following the links on those pages too. And so on.

So when we type in a keyword such as 'dog' into a search engine, it consults the index and returns a list of all the web pages on which that keyword appears. Typing in several keywords, e.g. 'dog' and 'bowl' would only return pages with both of these keywords, which helps to narrow down the set of results.

How are search results ranked?

The really clever bit about web searches is not the list of results, but the right rank order the results are put into. How do the search engine algorithms decide what to put top of the list?

Google's founders, Larry Page and Sergei Brin, recognised that the key to determining how relevant a particular result was likely to be lay in the links between other pages and the result. They realised that a high quality page is a page that has lots of links *pointing to it* from other web pages, particularly if they too were high quality results. This is shown in the illustration below, where the larger the circle, the higher the quality of the web page.



The cached and indexed copy of the (publicly accessible) Web on the servers of search engines also includes the links between them. This allows Page and Brin's PageRank algorithm to work out which pages are considered the highest quality to other web developers (as they add links to those into their own content). Thus, for many queries the Wikipedia entry will often be at the top of, or at least high up, the results list, not because of its accuracy or authority, or even because people click on this more than other results, but because lots of the other high quality search results link to it.

The actual algorithms that search engines use can be very complicated and are frequently tweaked to keep one step ahead of the 'search engine optimisation' (SEO) industry that tries to improve the ranking for its clients' pages. These days, the ranking of results is typically personalised: based on location, the history of what the user's searched for and clicked on before, and close on 200 other factors or 'signals'.

When teaching pupils about how search engines work, point out the 'sponsored' results which are shown above or to the side of those generated using this relevance algorithm. The sponsored results are also algorithmically generated, based on the keyword, some quality measure for the advert, the page it points to and often your search history. They're placed on a 'pay per click' basis: the search engine doesn't charge for showing the advert, but the advertiser pays when you click on it, so it's in their interests to only show the most relevant adverts here.

The mechanics will vary from one search engine to another, but a good search engine should also: filter out explicit content automatically, allow you to search within a particular site, allow results to be filtered by their location (e.g. just the UK) and by date range (e.g. just pages created or edited in the last year). Some search engines even allow results to be filtered by reading level, for example restricting the results to those written using shorter words or less complex sentences.

Classroom activity ideas

- Encourage pupils to use search engines for independent or guided research projects. Get pupils to experiment with the effect that adding in additional keywords or searching for phrases (by putting quotation marks around the phrase) has on a set of results.
- Demonstrate, and ask pupils to use, some of the more advanced search features, such as filtering by date and reading level. Show pupils how they can view the cached copy of a web page (for both Google and Bing this is hidden under the green drop-down next to the URL on the results page).
- Read through the Digital Schoolhouse notes on a simulation of how a search engine works, based on Google engineer Doug Aberdeen's presentation at the 2012 CAS Conference (see Further Resources below). Print off the resources and run this as an activity with your class.

Further resources

- Doug Aberdeen's simulation from the CAS conference, available at: www.computingatschool.org.uk/index.php?id=aberdeen.
- Useful list of advanced search keywords in Bing, available at: http://onlinehelp.microsoft.com/en-us/bing/ff808421.aspx.
- Short animated presentation 'How Search Works' by Matt Cutts, available at: www.youtube.com/watch?v=BNHR6IQJGZs.
- Peter Dickman's lecture 'How Google Search Works', available at: www.youtube.com/watch?v=C8v7AM1o7uM.
- Digital Schoolhouse simulation of how a search engine works: http://community.computingatschool.org.uk/files/3874/original.pdf.
- Eli Pariser's talk 'Beware online "filter bubbles"' (how individually focused our search results are), available at: www.ted.com/talks/eli_pariser_beware_online_filter_bubbles?language=en.

Communication and collaboration

Learning about wikis

How can you use computers to work with others?

There's more to computing than computer science. With the use of digital technology such as smartphones and the internet, it's hard to think of any sphere of life which hasn't been changed by the near ubiquitous nature of communication technology.

The national curriculum seeks to ensure that all pupils learn about some of the opportunities that networks offer for communication and collaboration.

Young people are usually comfortable using a range of digital technologies to communicate with one another (although you should not presume that they act safely and responsibly when doing so: see Safe and responsible use, pages 46–49). They are perhaps less skilled in using technologies to work collaboratively on shared projects.

Different technologies work with different-sized groups:

One-to-one
email
video calls
instant messaging

One-to-many
blogging
personal website
publishing on YouTube
podcasting
posting to social media

Many-to-one
searching the web
watching YouTube
browsing social media

Many-to-many
discussion forums
Wikipedia

We need to develop pupils' *understanding* of these technologies (and some critical discernment about their use) rather than just their ability to use any particular platform. The implementation of communication technology will change, but underlying principles are likely to remain the same.

Can communication technology be embedded across the whole curriculum?

Yes! Many schools are now using digital communication and collaboration technologies as part of their day-to-day work.

Can pupils communicate with other schools?

Again, yes! The internet can provide many opportunities for pupils in one class to communicate with or work collaboratively with pupils in another class.

There's so much that can be gained through even a simple, email based eTwinning project. Think of the scope for exploring 'contrasting localities' in geography, for practising other languages, or looking at a period in history from a global perspective.

What audience can pupils reach?

These days, it's easy for a teacher to set up a class blog, perhaps as open access so that a child's work can reach an audience, potentially, of close on three billion others. Blogs are also a great way to share what's happening in your class with your pupils' parents and with other teachers.

Blogs can be used as a basis for partnership projects with another class or group of classes, taking turns to respond to work that's posted (as in David Mitchell's QuadBlogging® projects: see Further resources). However, it's really important that comments posted to a class or school blog are moderated by a teacher before they're seen by pupils.

Blogging can be easily used to record and share pupils' work in computing. Even without blogging, pupils could share their programming work through community sites for tools such as Scratch and Kodu (taking care that all involved observe the terms and conditions that apply to these platforms).

How can pupils work collaboratively?

The internet makes it easy for pupils to work collaboratively online, just as they have always been able to do in class.

Web-based platforms such as Office 365 mean that pupils can work on files together, either by inviting comment and review from others, or through real-time collaboration. The efficiency with which joint projects can be undertaken and reviewed can make this a very exciting mode of work.

Teachers and pupils alike will be aware of the collaborative nature of Wikipedia. This can provide a good opportunity for pupils to become more discerning in evaluating digital content, and indeed to correct errors or add content to Wikipedia when they can. The Simple English Wikipedia is far less 'complete' than the main edition, and so it's practical for primary classes to 'adopt' pages here, editing or monitoring these for other users. Alternatively, teachers can set up their own wiki for their class, using one of a number of online tools.

Online collaborative working is a very important part of software development. Pupils themselves can get some experience in collaborative software development through the re-mix feature built into platforms such as Scratch, TouchDevelop and Kodu.

What ground rules should we establish?

It's important to establish an agreed set of rules for any online activities. Pupils need to be aware that terms and conditions do apply to them, even if they are rarely written in accessible language. You should brief pupils on what is expected of them. The key stage 2 programme of study expects pupils to recognise acceptable and unacceptable behaviour.

It's helpful to have a set of guiding principles here: pupils should behave online just as they would offline. This would include:

- not being deliberately hurtful
- taking care of shared resources
- being prepared to stand up for doing the right thing, even if it's unpopular
- not talking to strangers
- being honest.

Explain to pupils that most online systems automatically log the activities that take place in them: someone (or something) is watching what they do online!

www Further resources

- eTwinning: connect with classes across Europe, available at: www.eTwinning.net.
- 100 Word Challenge: carry out and share short literacy projects, available at: http://100wc.net/.
- Quadblogging®: collaborative blogging in groups of four classes across the world, available at: http://quadblogging.com/.
- Simple English Wikipedia, available at: http://simple.wikipedia.org/wiki/Main_Page.
- Wikipedia: Five pillars: the guiding principles behind Wikipedia, available at: http://en.wikipedia.org/wiki/Wikipedia:Five_pillars.
- Wikispaces Classroom: creating wikis in school, available at: www.wikispaces.com/content/classroom.

Productivity and creativity

Can we teach our old ICT topics?

The answer to this is yes! There are few, if any, topics from the old ICT curriculum that don't appear in the new computing curriculum.

At key stage 1 pupils should be taught to: 'use technology purposefully to create, organise, store, manipulate and retrieve digital content'.

At key stage 2 pupils should be taught to: 'select, use and combine a variety of software (including internet services) on a range of digital devices'. They design and create digital content as well as **programs** and systems, and they accomplish given goals, including 'collecting, analysing, evaluating and presenting data and information'.[1]

See pages 50–51 for more information on reusing old ICT units when planning a computing scheme of work.

How can we make ICT activities more meaningful for pupils?

David Jonassen and others coined the term 'meaningful learning'. They were thinking particularly about learning activities that involved using technology, but the principles can be applied more broadly. Jonassen's list[2] was:

- **active:** pupils should *do* something
- **constructive:** pupils should *make* something
- **intentional:** pupils should have some *say* in what they do or how they accomplish something
- **authentic:** link to pupils' direct experience, including that of school: look for connections with other areas of the curriculum
- **cooperative:** look for activities where pupils can learn with and from one another.

For example, pupils could work together to create and then analyse the results from an online survey of other pupils about their views on the breadth of the school's curriculum, choosing for themselves how they might present the results of their survey.

How should pupils go about project work?

It's important to find a balance between getting things done in the time available and developing good working habits for extended projects.

It's probably best to mix a range of short activities with more extended projects in which the processes of planning, implementing, revising and evaluating are fully explored. Working through the stages of a project in detail is good experience for this sort of work elsewhere.

Look for ways to get pupils involved in managing projects. This can include deciding what programs and equipment they'll need to use. The project management skills involved in creative media work are very similar to those required in software development.

What digital tools should pupils work with?

The programmes of study are quite careful not to specify particular digital media. Technology currently

[1] National Curriculum in England, *Computing Programmes of Study* (Department for Education, 2013).

[2] Jonassen, D. H. *et al.*, *Meaningful Learning with Technology* (Upper Saddle River NJ: Pearson, 2008).

available in most schools can be used for work across a very wide range of media including: text, images, sound, animations, video and 3D. Ensure that your pupils experience working across this full range. A PowerPoint presentation is likely to include text and images, and perhaps video, audio and animations.

Also aim to ensure that your pupils work on a variety of devices and are able to draw on web-based services, tablets, smartphones, digital cameras or other systems rather than just using traditional Windows PCs in their IT work.

How can creativity be taught?

Sir Ken Robinson defines creativity as 'the process of having original ideas that have value'[3]: creative work should be original, and this should at least mean that it's a pupil's own work, not something where they've simply filled in a blank or copied something. Creative work should also be of value: at the very least to the pupils themselves, but also to a wider audience.

As well as originality and value, creative work also implies that the pupil has made something. An emphasis on creativity recognises how powerful the process of making things for others is as a means to learning.

In the classroom, help pupils to become masters of the software tools and digital devices they use, helping them to develop confidence, competence and independence. Then encourage them to use them, playfully or experimentally, as a way of helping them express their own insights and ideas.

What can pupils do with data?

The computing curriculum includes a requirement for pupils to work with numerical **data**. This is an important application of computer systems and seems likely to become even more so in the future.

There's much you can do to provide pupils with an authentic experience of working with both small and large datasets. Pupils can generate interesting sets of data, or access large, open data repositories.

Online survey tools, such as Google Forms or Excel Online, allow pupils to design and deploy quick opinion polls or surveys, and then analyse, evaluate and present the results. Choosing topics of genuine interest to pupils, perhaps concerned with aspects of school life, can make activities like this much more engaging. Pupils should think about privacy and ethical aspects of such surveys. Good practice includes principles of informed consent and anonymity; the latter is particularly important as otherwise data protection legislation would apply when processing personal data.

[3] Robinson, K., *Out of Our Minds – Learning to Be Creative* (Capstone, 2011).

Classroom activity ideas

- Carry out activities that draw on automatically generated data, perhaps using sensors (e.g. a Scratch script to record the level of sound in class; see Further resources).
- Organise your pupils to analyse some *big* datasets made publicly available on the internet. Help them to use n-gram viewer to search for the occurrence of words or phrases in the vast number of books that Google have digitised and see how this changes over time (see Further resources). Analyse how search term popularity has changed over time, e.g. look at the relative popularity of searches for 'Britain's Got Talent' and 'The X Factor' over time in searches performed in the UK using Google Trends (see below).
- Discuss the ethical implications of data processing (i.e. what others do with our data). Ask pupils to think about the detailed profile which internet, email or search engine providers build up through analysing each user's activity, as well as to what uses this information might be put.

Further resources

- 'A picture is worth a thousand words: what we learned from 5 million books' lecture, available at: www.youtube.com/watch?v=5l4cA8zSreQ; see also n-gram viewer: https://books.google.com/ngrams.
- Classroom sound monitor on Scratch, available at: http://scratch.mit.edu/projects/20968943/.
- Google forms (www.google.co.uk/forms/about) or Excel Surveys (http://blogs.office.com/2012/11/16/excel-surveys/) for creating online surveys.
- Jonassen, D. H. *et al.*, *Meaningful Learning with Technology* (Upper Saddle River NJ: Pearson, 2008).
- Monte Carlo Method, available at: http://en.wikipedia.org/wiki/Monte_Carlo_method.
- Robinson, K., *Out of Our Minds – Learning to Be Creative* (Capstone, 2011).
- Using Google searches to predict flu: www.youtube.com/watch?v=uEt8NuqBvPQ; see also Google Trends: www.google.com/trends/.

Safe and responsible use

How can we keep children safe online?

Schools have a responsibility to keep pupils safe. The Byron Review,[1] Ofsted and others have emphasised that the best way to achieve this is to teach pupils how to keep themselves safe. Think of pupils cycling to school: the pupils are exposed to risks which could otherwise be avoided, but these risks are balanced by a range of benefits (independence, health, environment, road congestion, etc.). We do all we can to outweigh the risks by teaching pupils to cycle well and safely.

The new computing curriculum goes beyond just teaching **e-safety**, and states that key stage 2 pupils should be taught to:

> *use technology safely, respectfully and responsibly; recognise acceptable/unacceptable behaviour; identify a range of ways to report concerns about content and contact.*[2]

It's important to recognise that these requirements are a whole school responsibility. They should be taught across the curriculum and become part of the life of the school – this isn't just something for computing lessons.

By moving from a risk mitigation approach to a values-based approach that promotes the responsible use of technology, we can help develop the pupils' sense of moral responsibility and the 'grit' necessary for pupils to stand up for doing the right thing. Pupils will then be far better at coping with the challenges of secondary education and adolescence, and far less likely to fall prey to the more sinister aspects of the internet and other technologies.

What are the risks?

In *The Byron Review* Professor Tanya Byron outlined three broad categories of risk which children are exposed to through their use of digital technology: content, contact and conduct.

	Commercial	Aggressive	Sexual	Values
Content (child as recipient)	Adverts Spam Sponsorship Personal info	Violent/hateful content	Pornographic or unwelcome sexual content	Bias Racist Misleading info or advice
Contact (child as participant)	Tracking Harvesting personal info	Being bullied, harassed or stalked	Meeting strangers Being groomed	Self-harm Unwelcome persuasions
Conduct (child as actor)	Illegal downloading Hacking Gambling Financial scams Terrorism	Bullying or harassing another	Creating and uploading inappropriate material	Providing misleading info/ advice

Table taken from *Safer Children in a Digital World: The Report of the Byron Review*, p.16 (www.education.gov.uk/publications/eOrderingDownload/DCSF-00334-2008.pdf). **Contains public sector information licensed under the Open Government Licence v2.0: see** www.nationalarchives.gov.uk/doc/open-government-licence/version/2/.

[1] **Byron, T., *Safer Children in a Digital World: The Report of the Byron Review* (London: DCSF, 2008).**

[2] **National Curriculum in England, *Computing Programmes of Study* (Department for Education, 2013).**

Content

Children are naturally curious, and as teachers we hope to develop that curiosity – to establish a life-long love of learning. The Web has provided almost instant access to a wealth of information that pupils can access to further their learning and satisfy their curiosity.

Schools have effective filters that minimise exposure to inappropriate material in school, but this does not prevent pupils accessing such material outside of school, including on tablets or smartphones.

Both Bing and Google have safe-search modes (which can be locked in place) and these help prevent pupils from accessing particularly inappropriate content. In addition, a number of organisations have developed search engines targeted at children (for example www.swiggle.org.uk/), often through a combination of safe-search and custom-search tools in Google search.

Encourage parents to use the safe search filters on their search engine, and to request filtered internet access at home and on mobile devices, explaining how to do this and why it is a good idea.

But, even *with* filters in place, children may still encounter content that concerns them. Establish a 'no blame' culture in school so they feel they can alert you, or their parents, to such content. Many schools teach children to close the laptop, switch off the monitor or turn the tablet over if they find content they know they shouldn't see or that concerns them; again it's worth explaining this to parents and suggesting they do the same at home.

Byron identified commercialisation as another risk associated with exposing pupils to the internet. As teachers, we must help pupils to become discerning and critical about commercial aspects of the content they come across. For example, teach them about spam in email and how this can be filtered semi-automatically, as well as asking them to think about what sort of algorithms might be used in doing so.

Talk to pupils about advertising on the web and how this can be avoided through the use of browser plugins such as AdBlock, as well as the difference between sponsored and other results from search engines. It's also important to help pupils become aware of the difference between altruistically created content such as Wikipedia and many blogs, and content created with a perhaps hidden or implicit commercial purpose, e.g. apparently free online services that are sustained through using the user's data to help target advertising.

Contact

The new curriculum requires that pupils are taught who they can turn to if they have concerns over contact online. In most cases, pupils should talk to their parents or their teachers about such contact: if pupils report such concerns to you, this is likely to be covered by your safeguarding policy, so make sure you follow this carefully. Sometimes pupils might be too embarrassed to turn to either you or their parents, so it's worth introducing them to ChildLine and, in the case of key stage 2 pupils, CEOP (see Further resources).

Traditionally e-safety work in schools has included clear advice to children on not sharing personal information online. The curriculum includes this at key stage 1. Online privacy is an increasing matter of concern and there are broader issues here than 'stranger danger'. Pupils should be aware of their 'digital footprint', the data about them that is created by deliberately sharing content and through the automatic logging of all online activity. Whilst such logs are kept securely, many people are concerned about the uses to which such data could be put.

Classroom activity ideas

- Challenge older pupils to consider how algorithms can be designed to filter search results from a search engine to make them safe for children.
- Ask older pupils to think about the long-term implications of the data trails they leave behind them when they search the internet. Ask them to discuss: 'Who do you want to keep your data private from?' (From internet predators? From future employers? From the providers of search, internet and email services? From advertisers? From the school network manager? From government agencies?)

Conduct

The curriculum at key stage 1 requires that pupils learn to use technology 'respectfully'. At key stage 2 this is extended to 'responsibly', and pupils should also learn to recognise acceptable and unacceptable behaviour. Supporting children's moral development is a vital part of primary education, as well as a statutory requirement for a school's curriculum and, as part of 'spiritual, moral, social and cultural development', an element of all Ofsted inspections.

Lawrence Kohlberg's stages of moral development[3] offers one model for thinking about this:

1. Obedience and punishment orientation (How can I avoid punishment?)
2. Self-interest orientation (What's in it for me?)
3. Interpersonal accord and conformity (The good boy/girl attitude)
4. Authority and social-order maintaining orientation (Law and order morality)
5. Social contract orientation (Do unto others...)
6. Universal ethical principles (Principled conscience)

Under this model, we would hope to see pupils taking increasing responsibility for their own moral and ethical decisions and behaviour whilst at primary school. If schools take moral education seriously, many aspects of pupils' inappropriate conduct using technology can perhaps be avoided, or their consequences reduced.

Cyber-bullying
Even in primary schools, cyber-bullying is a common problem. Whilst this is more likely to happen outside of school, it's common for both bully and victim to be members of the same class or school and the cause and consequences may often be connected to school. As with bullying in general, a clear zero tolerance message is vital, together with a culture in which this can be reported in the knowledge that swift and effective action will follow. Alongside this, it's worth building up pupils' resilience to off-hand, unintentionally hurtful remarks from others and some recognition that not every online disagreement or critical comment constitutes bullying.

Copyright
There are generous exemptions from much copyright legislation for clearly specified educational use, but it's still important to teach and show best practice in the use of copyright material. This includes children (and teachers!) properly acknowledging the source of content and respecting any associated licence terms.

Creative Commons (see Further resources) provide a range of licences that allow those who create work to license it for re-use under a range of different conditions. You can teach pupils about this approach to sharing online and show them how they can search for, acknowledge and re-use Creative Commons licensed content in their own work. Both Google and Bing image search allow results to be filtered to show just images that have been licensed in this way.

Pupils own the copyright in their own work including the work they produce in school. As teachers, we should respect this by seeking permission from pupils and their parents before publishing pupils' work online. Asking parents to license this use of their children's work might seem over the top, but it's important that pupils learn about their rights as well as their responsibilities.

Terms and conditions
It's important that pupils and teachers respect the terms and conditions of any websites or other online services that they use. The terms and conditions of most online services run to many pages, but when signing up for new services, or asking pupils to do so, it's well worth checking through the sections on any age-restrictions as well as those on copyright and data privacy. US-based companies are required to abide by American COPPA (Children's Online Privacy Protection Act) legislation, which prevents their storing personal data on under 13s without parental consent. Thus, many US-based internet services prohibit under 13s from using the service. Primary school pupils using these services would be doing so without the operators' permission, which might be considered in breach of the UK Computer Misuse Act. Some services, including Office 365 and Google Apps for Education, allow schools to create accounts on behalf of children. Other websites, such as Scratch, allow teachers to create multiple accounts in their own name and share these with pupils.

Passwords
As more and more aspects of pupils' learning and life are mediated through online systems, it's important that they learn to protect their own online identity and respect the online identity of others. The sooner pupils can memorise and type in their own password (even a simple, short one) the better. Later on, encourage pupils to use long passwords that can't easily be guessed (e.g. CorrectBatteryHorseStaple), to use different passwords for different sites or services and to change passwords regularly. Discourage pupils from sharing passwords with one another (as this is usually their only way to prove who they are in any online system) or with their parents; many difficulties could arise through one parent impersonating their son or daughter in an otherwise secure 'walled garden' environment such as a school VLE or learning platform.

[3] Kohlberg, L., *Essays on Moral Development: Vol. 2, The Psychology of Moral Development* (Harper & Row, 1984).

Time to turn off

Finally, discuss with your pupils the opportunity cost associated with screen time. Time spent using a computer is time not spent doing other things, such as reading a (paper-based) book, learning a musical instrument, playing in a team and socialising face-to-face with family and friends. Whilst digital technology is seen by many as transformative of so many aspects of learning and life, many would count it a great shame if it came to dominate childhood to a greater extent than it already has. Helping children to become more discerning users of technology, knowing when it would be useful, and when it might be more of a distraction, is perhaps also one of our responsibilities as teachers.

Further resources

- Byron, T., *Safer Children in a Digital World: The Report of the Byron Review* (DCFS, 2008), available at: http://webarchive.nationalarchives.gov.uk/20130401151715/http://www.education.gov.uk/publications/eOrderingDownload/DCSF-00334-2008.pdf.
- Childnet's SMART rules: www.kidsmart.org.uk/beingsmart/.
- Creative Commons, for information and free licences to use, available at: http://creativecommons.org/.
- 'Digital Literacy & Citizenship from the South West Grid for Learning', teaching resources, available at: www.digital-literacy.org.uk/Home.aspx.
- Ofsted: 'Inspecting safeguarding in maintained schools and academies – Briefing for section 5 inspections', available at: www.ofsted.gov.uk/resources/inspecting-safeguarding-maintained-schools-and-academies-briefing-for-section-5-inspections.
- Thinkuknow.co.uk (CEOP), information and teaching resources for keeping children safe online, available at: www.thinkuknow.co.uk/Teachers/.
- UK Safer Internet Centre, for information and teaching resources, available at: www.saferinternet.org.uk.
- UNCRC (United Nations Convention on the Rights of the Child), for information and training on children's rights, available at: www.ohchr.org/en/professionalinterest/pages/crc.aspx.

Planning guidance

Planning a scheme of work

How do you plan a scheme of work?

It's sensible to establish a clear overall structure to your computing planning. This will help teachers and pupils find their way around the new curriculum and give some sense of continuity and progression to your planning. The national curriculum themes of computer science, information technology and digital literacy (foundations, applications and implications) are a good way to do this. Within each of these three themes you should aim to develop units of work that provide:

- a broad and balanced coverage of computing for each year group
- clear progression of understanding, knowledge and skills from one year to the next.

Many of your units might take the form of creative projects, in which pupils master the ideas of the curriculum through meaningful, practical activities. Once you have a set of units, map these back to the content of the programmes of study. Check that, taken as a whole, your units adequately cover all the content. If they don't, make some changes.

Don't see the curriculum as a limit to what you can teach. Some schools include units on computer hardware, touch-typing, cryptography or developing and designing content for the Web in HTML.

A good scheme of work should be continually developed as you assess pupils' learning and both you and they evaluate your teaching. This can be thought of as part of a continuous cycle of iterative development – 'debugging' units of work and looking at how new features can be implemented.

Adapting your existing content

In the transition from ICT to computing, the emphasis has shifted from skills in finding and presenting information to understanding the processes and applications of computation. Even so, don't think you have to throw away your old scheme of work. The best units are very likely to be relevant to the new computing curriculum, although you'll probably find you need to make room for new activities that:

- develop pupils' programming skills
- focus on computational thinking
- develop pupils' understanding of networks including the internet.

Adopting published schemes of work

Don't feel that you have to write your own scheme of work for computing. There are plenty of published schemes already available. Examples include:

- **commercial schemes:** e.g. *Switched on Computing* (Rising Stars), *100 Computing Lessons* (Scholastic) and Fantastict Computing Framework (Fantastict).
- **local authority schemes:** e.g. Bury, 'Bury Primary Computing Solution'; Somerset, 'A Computing Curriculum for Primary Learners' and Cambridgeshire, 'The Cambridgeshire Progression in Computing Capability Materials' (see Further resources).
- **schemes by individual teachers:** some of which have been shared freely through the CAS Community site: e.g. those by Phil Bagge, Matthew Wimpenny-Smith and Jon Chippindall (see Further resources).

You can choose to adopt or adapt these, taking into account the resources available, the interests and enthusiasms of you, your colleagues and pupils, and your school's approach to cross-curricular or integrated topics.

Guidance from Ofsted

In the past, Ofsted has provided detailed guidance on inspecting a school's ICT curriculum. The lead HMI for computing and e-safety, David Brown, gave some indications of his views on a good or outstanding computing curriculum in a presentation in July 2014 (see Further resources). It's well worth considering his expectations when planning or adapting a scheme of work. He suggested the following:

- *the curriculum is broad and balanced with all three computing strands covered well for all pupils, in computing lessons and/or across the school curriculum*
- *the contexts in which computing is taught are relevant to pupils' lives and reflect the increasing use of computing in the world of industry*
- *pupils are expected to use their computing knowledge, skills and understanding in realistic and challenging situations*
- *pupils have comprehensive knowledge and understanding of how to stay safe when using new technologies*
- *rigorous curriculum planning ensures the subject makes an outstanding contribution to pupils' spiritual, moral, social and cultural development.*[1]

How should we plan a computing lesson?

Don't assume that the conventional 'three-part' lesson must be followed. Often in computing pupils will be learning through making things and it's helpful to give longer periods of time for such projects. Not all lessons need to be about using a particular bit of software to do something. Even where pupils are learning to use new software, it can be worth starting with a discovery phase. They can then share their discoveries with one another, but make sure you correct any misconceptions.

Unplugged activities

Elements of the curriculum, particularly logical reasoning, algorithms, decomposition or how networks work, can be addressed without a computer, using pencil and paper or role-play activities. Both Barefoot Computing and CS Unplugged (see Further resources) have excellent activities for developing understanding rather than just practising coding skills.

Computational thinking should be embedded through the computing curriculum (see pages 6–17).

[1] Brown, D., Ofsted National Lead for Computing, 'Inspecting computing' slides (Barefoot Computing Conference).

Differentiation

Prior learning can vary quite widely across a class. Collaborative group work or paired programming (or other) exercises provide opportunities for pupils to teach new things to one another.

Allow enthusiastic pupils the autonomy (and critical support) to set their own challenges. For example, if some of your pupils are already adept at coding in Scratch, set them the challenge of coding the same algorithm in another language.

Think about inclusion.

- Is the task chosen so that all pupils' enthusiasm can be engaged and you've avoided issues about which some pupils might be particularly sensitive?
- How can you make appropriate adaptations for SEN/D or EAL pupils? Assistive technology can help with SEN/D, as can using an icon-based rather than text block-based programming environment: some dyslexic pupils are likely to find Kodu more accessible than Scratch for this reason.
- How can you help pupils who do not have access to digital technology at home become more confident and independent in computing?

Further resources

- Barefoot Computing, teaching resources, available at: http://barefootcas.org.uk/ (free, but registration required).
- Computing At School, community site resources, available at: http://community.computingatschool.org.uk/resources.
- Computing At School (CAS) Include: Computing Science for All, available at: http://casinclude.org.uk/.
- CS Unplugged, free activities and resources, available at: http://csunplugged.org/.
- ICTdotcom, ICT and Computer Planning by Matthew Wimpenny-Smith, available at: http://mwimpennys.primaryblogger.co.uk/uncategorized/ict-and-computing-planning/.
- Junior Computer Science, resources by Phil Bagge: www.code-it.co.uk/.
- Sheffield ILS eLearning Team 'SEN Computing Professional Learning Community', available at: http://sencomputing.wikispaces.com/.
- Somerset County Council 'A Computing Curriculum for Primary Learners', available at: http://bit.ly/1d1P2OK.
- The ICT Service 'Cambridgeshire Progression in Computing Capability Materials', available at: www.ccc-computing.org.uk/.

Teaching

What makes a good computing lesson?

There's a wealth of learning theory, academic research and professional practice, including Ofsted's expectations, that we can draw on to help address this crucial question. Good practice in computing is unlikely to be different from good practice across the primary curriculum. We can draw on what's effective in other subject areas which have much in common with computing: science, design and technology, art and design and music teaching.

What approaches are useful for teaching computing?

Educational theory can be mined for insights into how a new subject like computing might be taught. The pragmatic teacher is likely to draw on a blend of these approaches.

- **Experimenting:** Provide pupils with a chance to explore and tinker with new software or hardware when they first encounter it, so they can figure out their own mental model for how it works. This can be particularly effective with younger pupils.
- **Making:** A lot can be learnt through the process of making things to show to or share with others. This might be computer code, but it might also be PowerPoint presentations, web pages, edited video, digital photographs, etc.
- **Discussion:** Make the most of pupils' different insights, experiences and backgrounds by allowing them to share their ideas with one another and with others. Paired programming activities in class and online discussion forums are just two ways to facilitate this.
- **Connecting:** Learning from others need not be limited to the classroom: encourage pupils to explore others' solutions to problems on the Kodu or Scratch community sites, for example, or to search online for solutions to problems.
- **Direct instruction:** For some ideas in computing, the traditional, direct instruction approach can work well. Complex ideas such as variables, how the internet works or how search engines operate could be learnt using discovery-based approaches, but direct teaching is likely to be more effective.
- **Practise:** Don't assume that once pupils have demonstrated they can do something or understand an idea that their learning is secure. Provide opportunities for them to practise applying their skills, knowledge and understanding.

What does Ofsted expect?

Ofsted's expectations of good or outstanding lessons are the same irrespective of subject, and are outlined in the current edition of the *School inspection handbook* (Ofsted 2014).

The *School inspection handbook* makes clear the importance of inclusion, as discussed in relation to planning for computing (page 51). Thus, for teaching to be considered outstanding:

> *almost all pupils currently on roll in the school, including disabled pupils, those who have special educational needs, disadvantaged pupils and the most able, are making sustained progress that leads to outstanding achievement.*[1]

In his presentation on inspecting computing, David Brown made some suggestions for what good or outstanding teaching in computing might look like.

He recommended that:

- *it is informed by excellent subject knowledge and understanding of continuing developments in teaching and learning in computing*
- *it is rooted in the development of pupils' understanding of important concepts and progression within the lesson and over time; it enables pupils to make connections between individual topics and to see the 'big picture'*
- *lessons address pupils' misconceptions very effectively; teachers' responses to pupils' questions are accurate and highly effective in stimulating further thought*
- *teachers use a very wide range of innovative and imaginative resources and teaching strategies to stimulate pupils' active participation in their learning and secure good or better progress across all aspects of the subject.*[2]

When commenting on pupils' achievement in computing, David Brown suggested that this would be good or outstanding if:

- *pupils demonstrate excellent understanding of important concepts in all three strands of the computing curriculum and are able to make connections within the subject because they have highly developed transferable knowledge, skills and understanding*
- *pupils show high levels of originality, imagination, creativity and innovation in their understanding and application of skills in computing*

but would be regarded as inadequate if:

- *pupils rarely demonstrate creativity or originality in their use of computing but seem confined to following instructions.*[3]

What about beyond the classroom?

Look for ways in which pupils can take their learning further. Here are just a few examples.

- Code Club (see Further resources) run after-school coding clubs in around 2,000 primary schools and make their activities available for others to use as they wish. Typical clubs are run by volunteers, although teacher involvement is also needed. Code Club provide an introductory Scratch programming course and a more advanced Scratch coding course, as well as courses that introduce the basics of HTML coding for web-development and Python programming.
- Many schools have found it helpful to institute a system of pupil 'digital leaders', who can help teachers and other pupils with some limited tech support, as well as being the first to try out new software and hardware and even advising on the school's technology policies. Typically, schools run an open application process for these roles, inviting potential digital leaders to set out in writing why they would be well suited to the role.
- Activities such as CoderDojo and Young Rewired State (see Further resources) rely on parental support for primary aged pupils and involvement from those working in the software industry.
- Some primary pupils might, with parental permission, become active participants in online communities, such as those around Kodu, Scratch or even YouTube and blogging. Others might pursue more advanced coding skills, perhaps using online interactive tutorials such as those offered by Codecademy (see Further resources), or teaching themselves how to develop for Windows Phone, Android or iOS.

Try to find ways in which this sort of advanced learning beyond school can be brought in to class and shared with other pupils.

www Further resources

- David Brown (Ofsted) 'Inspecting computing' (Barefoot Computing Conference) slides.
- Codecademy teaching resources, available at: www.codecademy.com/schools/curriculum.
- Code Club network of after-school coding clubs, available at: www.codeclub.org.uk/.
- CoderDojo network of free computing programming clubs, available at: https://coderdojo.com/.
- Cousin, G., 'An introduction to threshold concepts' (2006), available at: www.et.kent.edu/fpdc-db/files/DD%2002-threshold.pdf.
- Hattie, J., *Visible Learning for Teaching: Maximising Impact on Learning* (Routledge, 2009).
- Papert, S., *Mindstorms: Children, Computers, and Powerful Ideas* (Basic Books, 1980).
- The Sutton Trust Education Endowment Foundation Teaching and Learning Toolkit, for information on research and guidance on using resources for disadvantaged pupils, available at: http://educationendowmentfoundation.org.uk/toolkit/.
- Young Rewired State community of young digital makers, available at: www.yrs.io/.

[1] ***School inspection handbook*** **(Ofsted, 2014).**
[2] **Brown, D., Ofsted National Lead for Computing, 'Inspecting computing' slides (Barefoot Computing Conference).**
[3] **ibid.**

Assessment

Assessing and tracking progress

How can we collect evidence of learning?

When Ofsted reported on ICT in schools, assessment came in for particular criticism. Assessing computing can provide some particular challenges.

- It's too easy to focus on the outcomes of a task at the expense of assessing the learning that takes place in the process.
- It's too easy to focus on assessing pupils' skills in using particular software instead of assessing their knowledge and understanding.
- If pupils have worked with a partner or in a group to complete a project, how can you assess each individual's learning?

You can do much to meet these challenges and develop robust approaches to assessment, so that you can form a judgement about what individual pupils can do, know and understand, as well as helping pupils themselves reflect on how they've applied computational thinking.

Blogs for showcasing, reflection and feedback

Probably, the most effective thing you could do is to start a class blog. Ask pupils to use this to upload the outcomes of their work and document the computational thinking processes they worked through, focusing on any challenges they overcame.

Blogs provide a way for pupils to get feedback through the comments section. Invite pupils to respond to any questions raised. You can create a tagging system so you and your pupils can use their blog to track progress. A blog begun in Year 1 and continued up to Year 6 would provide rich evidence of both progress and attainment.

Other approaches

Naace suggest using an interview at the end of a project. A pupil might explain the computational thinking they used in solving a problem, but could also reflect on what and how they have learnt.

There's a place for formal testing in computing. In programming work, code tracing and debugging challenges are useful ways of assessing both specific knowledge of a programming language as well as logical reasoning and other problem-solving skills.

Evidence for pupils' computational thinking will be found in how they approach projects, but well-designed questions might provide one way of assessing this more directly. The Beaver Challenge (see Further resources) is a series of online questions assessing computational thinking.

How can we track progress?

The 'Progression Pathways Assessment Framework' is used by many for both planning and monitoring progression in computer science. It was derived from CAS's original computer science curriculum and provides detailed treatment of progression across six strands:

- algorithms
- programming and development
- data and data representation
- hardware and processing
- communication and networks
- information technology.

The authors, Mark Dorling and Matthew Walker, explain:

> *The progression through each strand of computing is broken down into rows. The rows are colour coded (like karate belts) to help the teacher to assess whether students are showing competence at different levels and recognise achievement or attainment.*

> *Schools can choose to assign arbitrary values (levels) to the coloured rows if they would like to use them with existing reporting systems.*
>
> *The focus of this assessment framework is progression through and across the strands of computing. If you plan to use this assessment framework with your existing assessment/reporting system then you can agree the benchmark 'level' for the pupils entering a particular key stage and assign the arbitrary benchmark value (level) to the appropriate progression statements for each strand.*[5]

They recommend that primary teachers focus on the badge statements from the Pink to Purple rows.

How can we assess attainment?

The old national curriculum levels have been removed and not replaced. The statutory attainment target is clear:

> *By the end of each key stage, pupils are expected to know, apply and understand the matters, skills and processes specified in the relevant programme of study.*[6]

Computing in the national curriculum: A guide for primary teachers (see Further resources) outlines an approach to assessment based on tracking achievement of the individual statements from the programmes of study. The advantage of a granular method like this, similar to EYFS assessment, is that it shows pupils, parents and teachers exactly what has been achieved and what aspects of the curriculum remain targets for subsequent work.

Evidence of attainment

Even just one Scratch script, such as this for a duck shoot game: http://scratch.mit.edu/projects/15907506/#editor, provides evidence of attainment for the key stage 2 programme of study.

From the Scratch scripts themselves, we have evidence of:

- write programs that accomplish specific goals
- use sequence in programs
- work with various forms of input (keyboard and mouse in this case)
- design programs that accomplish specific goals
- design and create programs
- use repetition in programs (forever loop, two different repeat until loops)
- simulate physical systems
- use selection in programs (if ... then ... else)
- work with variables (score).

If pupils had also explained how they'd solved the problems, then you might also have evidence of a number of the 'logical reasoning' statements.

SEN

Pupils with special educational needs working below the level of the programme of study for their key stage should be assessed using the P-scale statements, as in the past. There's much in these statements which reflect emergent computational thinking.

Digital badges

Digital badges can provide a great way to record and reward pupils' attainment in computing. One approach (used by Rising Stars with Makewav.es) would be to have a badge for each of the bullet points in the programme of study, with clear criteria for each particular bullet point. If you're using the 'CAS Progression Pathways Assessment Framework', there are Makewav.es badges for these too.

Further resources

- Bebras International Contest on Informatics and Computer Fluency and Computational Thinking Challenge, available at: www.bebras.org/ and www.beaver-comp.org.uk/.
- Berry, M., *Computing in the national curriculum: A guide for primary teachers* (Computing At School, 2013), available at: www.computingatschool.org.uk/data/uploads/CASPrimaryComputing.pdf.
- Brennan, K. and Resnick, M., 'New frameworks for studying and assessing the development of computational thinking' (2012), available at: http://web.media.mit.edu/~kbrennan/files/Brennan_Resnick_AERA2012_CT.pdf.
- DfE (2014) P-scales: attainment targets for pupils with SEN, available at: www.gov.uk/government/publications/p-scales-attainment-targets-for-pupils-with-sen.
- Dorling, M. and Walker, M., Progression Pathways Assessment Framework (2014), available at: http://community.computingatschool.org.uk/resources/2324.
- Makewav.es badges for Progression Pathways, available at: https://www.makewav.es/cas and for the Attainment Targets, available at: https://www.makewav.es/badges/18419/.
- Switched on Computing Scratch debugging challenges, available at: http://scratch.mit.edu/studios/306100/.

[5] **Progression Pathways Assessment Framework (Computing At School).**
[6] **National Curriculum in England, *Computing Programmes of Study* (Department for Education, 2013).**

Running CPD sessions

This section provides guidance about delivering computing CPD sessions. This guidance can be used in conjunction with the two PowerPoint files provided on the CD-ROM that accompanies the toolkit.

Preparation

Advertising
Advertise to local primary schools that you are offering two computing training sessions as part of the rollout of *QuickStart Computing*. Use emails and social media (e.g. Twitter), and your own personal contacts at schools as well as local authorities.

Location
A local school which will allow the use of their computing facilities is ideal. Failing that, any room can be used as long as you have access to a laptop, internet connection and data projector.

Refreshments
Ensure refreshments are provided for all your attendees.

Timings
The outlines provided here assume two, three- to four-hour CPD sessions, that would be held during INSET; one at the start of a school term and the second at the end. These sessions could be adapted to fit into three twilight sessions after school.

Charging
The materials are free and must not be charged for.

Adapting content
Adapt the resources provided here for use with your audience. For example, you may wish to:

- deliver three CPD sessions, rather than two
- focus on specific content, as requested by your group
- edit the PowerPoint presentations by adding your own content, or deleting some of what's there
- swap the order of sections within the CPD sessions.

It is important to be flexible when running the CPD sessions – be prepared to drop certain activities if attendees would benefit from spending more time on a particular concept.

Tips and advice

- Try to make sessions as interactive as possible by including hands-on activities or group discussion where all attendees are involved. Avoid long periods of talking from the front; encourage participation by asking questions.
- The best way to learn to code is to code. A great way to learn about the computing curriculum is to plan some lessons and units of work together.
- Share your enthusiasm for the subject.
- Provide suggestions for what teachers should do after the session has finished. Ensure you outline a clear plan for what participants need to do before the next session.

CPD Session 1

Resources

- Welcome to *QuickStart Computing*
- Session 1 presentation template
- Skills and knowledge audit form (1 per delegate)
- Resources audit form (1 per delegate)
- *QuickStart* handbooks (1 per delegate, either hard copy or pdf files)

Hardware

- Bee-Bot mat
- Bread, butter, jam, knives, plates, napkins (enough to make a jam sandwich)
- Laptop per delegate with access to Scratch 2.0 online (or Scratch 2.0 installed). Ensure you request this when sending invites
- Data projector
- Internet access and wifi information
- Bee-Bot per group (ensure you request this when sending invites)
- Four-way extension cables for laptops are useful.

Session outline

Welcome (5 mins)

- Brief welcome
- Wifi access information
- Structure of the CPD session.

Why are we here? (10 mins)

- Play the Welcome to *QuickStart* video, or give a general introduction to the *QuickStart* content (see User guide on page 4 of this handbook). It's worth emphasising that computing is more about computational thinking and creativity than 'coding'. Explain how computing is made up of computer science, IT and digital literacy.
- Time permitting, you may wish to play Simon Peyton Jones' TedEx talk about teaching creative computer science: www.youtube.com/watch?v=Ia55clAtdMs.

How CPD works (5 mins)

- Refer to the *QuickStart* roadmap (see page 5 of this handbook).

Subject knowledge and skills audit (10 mins)

- Ask attendees to fill in a knowledge and skills audit form. You may find you need to explain some of the vocabulary here.
- Discuss which PoS statements attendees have least confidence with.

Computational thinking (60 mins)

Introduction (10 mins)

- With examples, discuss and define the key computational thinking concepts and processes:
  - logical reasoning (predicting and analysing)
  - algorithms (making steps and rules)
  - decomposition (breaking down into parts)
  - patterns and generalisation (spotting and using similarities)
  - abstraction (managing complexity).

Activity: A jam sandwich algorithm (25 mins)

(See Classroom activity ideas on page 8 of this handbook.)

- Explain that in this session, attendees will be writing an algorithm to make a jam sandwich.
- You may wish to play the Introducing algorithms video from the CD-ROM.
- Ask teachers to split up into pairs and write an algorithm for creating a jam sandwich.
- Bring the group back together. Ask for a volunteer to come to the front to make a jam sandwich, following an algorithm provided by the group.
- You can play Phil Bagge's outtake video if you wish: www.youtube.com/watch?v=leBEFaVHllE
- Discuss what pupils might learn through such an activity.

Activity: Guess my number (25 mins)

(See Classroom activity ideas on pages 11–12 of the handbook.)

- Explain the game to the group (see pages 11–12 of this handbook).
- Split attendees into groups and ask them to come up with the most efficient way of guessing a number from 1–1000, only asking questions that can be answered with a 'yes' or 'no' answer.
- Bring the group back together and ask one member of each group to explain their method.
- Test one or more of these methods, to see how efficient they are.
- Summarise the different algorithms that could

be used to guess the number (random search, sequential search and binary search) and emphasise how a binary search is the most efficient algorithm.

- You can demonstrate this as a Scratch program: http://scratch.mit.edu/projects/12976768/#editor.
- Discuss what other problems this algorithm might be used for (e.g. finding words in a dictionary, or books in a library).
- Discuss what pupils might learn from this activity.

BREAK (15 mins)

Programming (60 mins)

Introduction (10 mins)

- You may wish to play the Introduction to programming video from the CD-ROM.
- Explain the relationship between programming, algorithms and code. Emphasise that computing includes both, and that we see programming as the best way to develop and practise computational thinking.
- Discuss and define the key programming concepts of sequence, repetition, selection and variables that are mentioned in the PoS.

Activity: Programming a Bee-Bot (25 mins)

Summary: Some simple programming exercises using a Bee-Bot. (See Classroom activity ideas on page 21 of this handbook for examples.)

- Split attendees into pairs/groups and ask them to write a program to move the Bee-Bot from one position to another (depending on the Bee-Bot mats available). Ask them to record their algorithm, predict what will happen, test and then debug as necessary.
- Provide instructions for a Bee-Bot that include an error. Ask attendees to debug the program.
- Bring the group back together and ask one pair to highlight the bug and how they fixed it.
- You can use the Scratch Bee-Bot simulator at http://scratch.mit.edu/projects/20050141/#editor if you wish.
- Discuss what pupils might learn through an activity like this.

Activity: Creating 'crystal flowers' in Scratch (25 mins)

- Ask participants to work out the algorithm and then the program to draw a square.
- Ask them to work out the algorithm and then the program to draw a more complex shape.
- Show attendees a Scratch script for creating a crystal flower, such as http://scratch.mit.edu/projects/39995570/#editor. Explain what each part of the script does (reference repetition and variables).
- You can show the Python equivalent code if you'd like and ask participants to spot the connections, but emphasise that there's no requirement for text-based programming in the primary PoS.
- Ask them to make some changes to this script to see what happens.
- Discuss what pupils might learn through this activity.

CPD action plan – breakout session (10 mins)

- Ask teachers to split into smaller groups of 2–3 and spend some time discussing:
  - how they plan to put into practice what they have learned (i.e. running some of the activities with pupils, creating a 'crystal flower' in Scratch)
  - how they plan to deliver computing CPD to their class teachers when they return to school and what support they will need to do this (for example, discuss with senior management team).
- Ask each group to share their plans.

General discussion/questions (15 mins)

Allow the conversation to flow, but you might like to use the following questions to facilitate a discussion.

- How are teachers using computational thinking in their jobs?
- Can the group think of ways in which computational thinking is used across the curriculum?
- What challenges do the group expect with teaching pupils to program Bee-Bots or in Scratch?
- How can teachers best learn programming themselves?

Conclusion and close (5 mins)

- Reminder of follow-up session date.
- Things to do before then:
  - finish knowledge and skills audit form
  - create a CPD action plan
  - start running internal CPD sessions.

CPD Session 2

Resources

Session 2 presentation template

- Simple message slips for Activity 1 (see suggested template in diagram on page 34 of handbook)
- Resources for Activity 2: www.computingatschool.org.uk/index.php?id=aberdeen

Hardware

- Laptop
- Data projector
- Internet access
- Wifi access information
- Enough six-sided dice for all participants.

Session outline

Welcome (5 mins)

- Brief welcome
- Wifi access information
- Structure of the CPD session.

Reflection on school-based CPD (20 mins)

- Ask attendees to split into small groups to reflect on how the CPD has gone so far.
- Bring the group back together and discuss.

The internet (60 mins)

Introduction (10 mins)

- Ask participants to discuss how they'd explain the difference between the internet and the World Wide Web.
- Provide a brief introduction on the internet.
- You may wish to play the How the internet works video from the CD-ROM.

Activity: How data is passed between computers (25 mins)

(See Classroom activity ideas on page 34 of this handbook.)

- Explain that the group will be carrying out an 'unplugged' activity to model how the internet passes packets of data.
- Discuss how the activity will work.
- Provide three message slips for each participant.
- Run the activity.
- Summarise the key learning points from the activity. Allow time for participants to ask questions.

Activity: How a search engine works (25 mins)

(See Classroom activity ideas on page 41 of this handbook: www.computingatschool.org.uk/index.php?id=aberdeen.)

- Explain that this is an 'unplugged' activity to model how a search engine ranks results.
- Summarise how the activity will work.
- Stick the web pages up around the room.
- Run the activity.
- Discuss the key learning points from the activity.

BREAK (15 mins)

Planning (20 mins)

- You may wish to play the Planning a scheme of work video from the CD-ROM.
- Discuss options for creating or adapting a computing scheme of work.
- Ask teachers to split out into small groups to plan a computing lesson.
- Ask each group to summarise their plans.

Teaching (20 mins)

- You may wish to play the Approaches to teaching computing video from the CD-ROM.
- Open up the floor for a general discussion about teaching approaches for computing and encourage individuals to share their experiences.
- If discussion flags, ask about whether participants think teaching computing and teaching ICT are that different?

Assessment (20 mins)

- You may wish to play the Assessing and tracking progress video from the CD-ROM.
- Provide a few examples of Scratch programs that you (or pupils) have created, or just browse the gallery of uploaded Scratch projects at http://scratch.mit.edu/explore/?date=this_month.
- Ask participants to split into small groups and use the Progression Pathways, or the Attainment Targets (PoS statements) to assess each program.
- Bring the group back together to share thoughts and ideas.

General discussion/questions (15 mins)

Use the following questions to facilitate a discussion:

- How would you teach pupils how the internet and search engines work?
- How would you structure your scheme of work?
- What makes a good computing lesson?
- What do you see as the challenges for assessing computing?

Conclusion and close (5 mins)

Next steps

Here are some ways for you to get more involved in computing and computer science education.

Have a go!

You're likely to feel much more confident teaching computer science after spending some time writing some code of your own. Why not have a go at developing your own interactive game, or creating a scripted animation in Scratch or ScratchJr linked to a topic you're teaching (see e.g. the Barefoot Vikings animation: http://barefootcas.org.uk/programme-of-study/use-sequence-in-programs/upper-ks2-viking-raid-animation-activity/).

Join CAS

Computing At School (CAS) is a grass-roots, school-led organisation, and its energy, creativity and motivating force comes from its members. Membership is free and allows access to a wide range of teaching resources and the community forums: www.computingatschool.org.uk/.

Join the NoE

The Network of Teaching Excellence in Computer Science (NoE) is co-ordinated by CAS and supported by BCS (The Chartered Institute for IT), Department for Education, Microsoft UK, Microsoft Research, Google, Ensoft and The Council of Professors and Heads of Computing (CPHC).

The aim of this programme is to build a high-quality, sustainable CPD infrastructure by nurturing collaboration between employers, universities, professional bodies, schools and teachers.

You can register your school for free. For more information, see: www.computingatschool.org.uk/index.php?id=member-schools.

Become a Master Teacher

CAS Master Teachers deliver local CPD and play a vital role in developing computing provision in schools across the country.

If you can answer '**yes**' to the following, then the Master teacher programme is for you!

- Are you a teacher in a state maintained school?
- Would you like funding to develop your skills and knowledge of computing in the new national curriculum?
- Are you an experienced teacher with 'good with outstanding' or 'outstanding' teaching seen in your recent lesson observations?
- Can you confidently engage with your peers in a professional environment?
- Do you have the ability to design and deliver practical and interactive workshops for teachers with appropriate course material?
- Do you have a passion about sharing best practice in teaching and learning?

To find out more, visit: www.computingatschool.org.uk/index.php?id=noe-master-teachers.

Join the Microsoft Educator Network

If you're using Microsoft's products, consider joining their educator network. Access free software and tools for student engagement, and view learning activities and tutorials created by educators, with a focus on increasing achievement and participating in a global conversation about education: www.pil-network.com/.

Join ScratchED

ScratchED is an online community for teachers interested in, or already actively working with, the Scratch authoring environment. With ScratchED, educators can share stories, exchange resources, ask and answer questions, and find other educators: http://scratched.gse.harvard.edu/.

BCS Certificate in Computer Science Teaching (CST)

The BCS certificate provides teachers with professional recognition that they are competent teachers of the computer science elements of computing. It is accredited by the BCS and is open to all qualified teachers who are currently teaching computing. For more information, see: www.computingatschool.org.uk/index.php?id=certificate.

MOOCs

There are a number of massive open online courses (MOOCs) for computer science in education; for example, Harvard's CS50x (www.edx.org/course/introduction-computer-science-harvardx-cs50x) and UEA's Teaching Computing. Microsoft also have an extensive portfolio of free online courses: www.microsoftvirtualacademy.com/.

Resources

Websites

Computing At School (CAS) host a large resource bank of plans, resources and activities. CAS is free to join: http://community.computingatschool.org.uk/door.

The BCS Barefoot Computing project is developing concept guides and exemplar activities. Free, but registration required: http://barefootcas.org.uk/.

Naace (the ICT association) and CAS have developed joint guidance on the new computing curriculum: www.computingatschool.org.uk/index.php?id=primary-national-curriculum-guidance.

New Zealand based CS Unplugged produce an excellent collection of resources exploring computer science ideas through classroom- rather than computer-based activities: http://csunplugged.org.

CAS CPD Co-ordinator, Mark Dorling, has made available a large collection of lesson plans and other resources through the Digital Schoolhouse project for London schools: www.digitalschoolhouse.org.uk/.

CAS Primary Master Teacher, Phil Bagge, has shared detailed lesson plans for many computer science and digital literacy topics: http://code-it.co.uk/philbagge.html.

A group of teachers and teacher trainers convened by the NCTL and chaired by Toshiba's Bob Harrison worked together to curate resources for initial teacher training for the computing curriculum: bit.ly/ittcomp.

There is a large collection of resources for teaching all aspects of computing on the TES website, for both KS1 and KS2. There's also a discussion forum online. Free, but registration is required: https://community.tes.co.uk/search/?SB=postcount_i%20desc&tc=1%2Fsubject%2Fictinformationtechnology.

Code Club provide detailed plans and resources for extra-curricular clubs, which might be adapted for use within the school curriculum. Free, but registration required: www.codeclub.org.uk/.

Code Club Pro provides training for teachers on the computing curriculum: www.codeclubpro.org/.

In the US, code.org make available a range of high quality curriculum materials and activities linked to programming and computational thinking: http://code.org/.

The BBC has an extensive set of resources for pupils, linked to the new computing curriculum: www.bbc.co.uk/schools/0/computing/.

BBC Two's Cracking the Code: www.bbc.co.uk/programmes/b01r9tww/clips.

The Raspberry Pi foundation has a good collection of high quality resources, which are relevant to other platforms as well as the Pi: www.raspberrypi.org/.

Resources for teaching safe, respectful and responsible use of technology are widely available. Childnet International and CEOP's Thinkuknow are both good starting points for exploring these topics: www.childnet.com/ and www.thinkuknow.co.uk/.

SWGfL provide free access to digital literacy materials: www.digital-literacy.org.uk/Home.aspx.

Futurelab is an independent charitable organisation commissioning research into, and providing funding for, cutting-edge applications of technology in education. Their archive is also a useful resource: www.futurelab.org.uk/.

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Knowledge and skills audit form

Use this form (or the interactive audit tool provided at www.quickstartcomputing.org) to audit your computing knowledge and skills.

The relevant statement from the Computing PoS has been referenced in brackets.

	I am not confident I can do this.	**I am confident I can do this.**	**I am very confident I can do this.**
Section 1: Computer science			
I can explain what an algorithm is (KS1: S1)			
I can explain how algorithms are implemented as programs on digital devices (KS1: S1)			
I can explain how programs execute by following precise and unambiguous instructions (KS1: S1)			
I can create simple programs (KS1: S2)			
I can debug simple programs (KS1: S2)			
I can design programs that accomplish specific goals (KS2: S1)			
I can write programs that accomplish specific goals (KS2: S1)			
I can debug programs that accomplish specific goals (KS2: S1)			
I can control or simulate physical systems (KS2: S1)			
I can solve problems by decomposing them into smaller parts (KS2: S1)			
I can use sequence in programs (KS2: S2)			
I can use selection in programs (KS2: S2)			
I can use repetition in programs (KS2: S2)			
I can work with variables (KS2: S2)			
I can work with various forms of input (KS2: S2)			
I can work with various forms of output (KS2: S2)			
I can use logical reasoning to predict what will happen when I run a program (KS1: S3)			
I can use logical reasoning to predict what will happen when I read through computer code (KS1: S3)			
I can use logical reasoning to explain how some algorithms work (KS2: S3)			
I can use logical reasoning to detect errors in algorithms (KS2: S3)			
I can use logical reasoning to correct errors in algorithms (KS2: S3)			
I can use logical reasoning to detect errors in programs (KS2: S3)			
I can use logical reasoning to correct errors in programs (KS2: S3)			
I can explain how computer networks work, including the internet (KS2: S4)			

	I am not confident I can do this.	I am confident I can do this.	I am very confident I can do this.
I can explain how computer networks can provide multiple services such as the World Wide Web (KS2: S4)			
I can explain how search results are selected (KS2: S5)			
I can explain how search results are ranked (KS2: S5)			
Section 2: Information technology			
I can use technology purposefully to create digital content (KS1: S4)			
I can use technology purposefully to organise digital content (KS1: S4)			
I can use technology purposefully to store digital content (KS1: S4)			
I can use technology purposefully to retrieve digital content (KS1: S4)			
I can use technology purposefully to manipulate digital content (KS1: S4)			
I can explain how to use search technologies effectively (KS2: S5)			
I can select, use and combine a variety of software (including internet services) on a range of digital devices (KS2: S6)			
I can design a range of programs, systems and content that accomplish given goals (KS2: S6)			
I can create a range of programs, systems and content that accomplish given goals (KS2: S6)			
I can collect, analyse, evaluate and present data (KS2: S6)			
I can collect, analyse, evaluate and present information (KS2: S6)			
Section 3: Digital literacy			
I can discuss common uses of information technology beyond school (KS1: S5)			
I can explain how to use technology safely (KS1: S6)			
I can explain how to use technology respectfully (KS1: S6)			
I can explain how to use technology responsibly (KS2: S7)			
I can explain how to keep personal information private (KS1: S6)			
I can explain where to go for help and support when pupils have concerns about content or contact (KS1: S6)			
I can discuss the difference between acceptable and unacceptable behaviour online (KS2: S7)			
I understand what opportunities computer networks offer for communication and collaboration (KS2: S4)			
I can explain how to be discerning in evaluating digital content (KS2: S5)			

Glossary

Acceptable Use Policy (AUP): An Acceptable Use Policy comprises a set of rules applied by the owner/manager of a network, website or large computer system that defines the ways in which the network, site or system may be used.

Algorithm: An unambiguous set of rules or a precise step-by-step guide to solve a problem or achieve a particular objective.

Command: An instruction for the computer to execute, written in a particular programming language.

Computational thinking: Thinking about systems or problems in a way that allows computer systems to be used to model or solve these.

Computer networks: The computers and the connecting hardware (wifi access points, cables, fibres, switches and routers) that make it possible to transfer data using an agreed method ('protocol').

Creative Commons: A licensing scheme where the creator of an original work allows others to use it without seeking further permission, subject to a number of agreed conditions: www.creativecommons.org.

Data: A structured set of numbers, possibly representing digitised text, images, sound or video, which can be processed or transmitted by a computer, also used for numerical (quantitative) information.

Debug: To fix the errors in a program.

Decomposing: The process through which problems or systems are broken down into their component parts, each of which may then be considered separately.

Domain Name Service (DNS): The distributed automatic system that converts domain names into the IP addresses which are used for routing packets via the internet.

Encrypt: To securely encode information so that it can only be read by those knowing both the system used and a secret, private key.

E-safety: Used to describe behaviours and policies intended to minimise the risks to a user of using digital technology, particularly the internet.

Generalisation: A computational thinking process in which general solutions or models are preferred to or derived from particular cases.

Hardware: The physical systems and components of digital devices; see also software.

Hypertext mark-up language (HTML): HTML is the language in which web pages are composed.

Hypertext transfer protocol (HTTP): HTTP is the standard protocol for the request and transmission of HTML web pages between browser and web server.

Input: Data provided to a computer system, such as via a keyboard, mouse, microphone, camera or physical sensors.

Interface: The boundary between one system and another – often used to describe how a person interacts with a computer.

Internet Protocol (IP) addresses: Numeric addresses uniquely specifying computers directly connected to the internet, also used on private networks to uniquely identify computers on that network.

Loop: A block of code repeated automatically under the program's control.

Network server: A computer connected to a local area network providing services – such as file storage, printing, authentication, web access or email – automatically to other computers on the network.

Open source software: Software in which the source code is made available for others to study, and typically adapt, usually with few if any restrictions.

Operating system: The programs on a computer which deal with internal management of memory, input/output, security and so on, such as Windows 8 or iOS.

Output: The information produced by a computer system for its user, typically on a screen, through speakers or on a printer, but possibly through the control of motors in physical systems.

Packets of data: A small set of numbers that get transmitted together via the internet, typically enough for 1000 or 1500 characters.

Programmable toys: Robots designed for children to use, accepting input, storing short sequences of simple instructions and moving according to this stored program.

Program: A stored set of instructions encoded in a language understood by the computer that does some form of computation, processing input and/or stored data to generate output.

Repetition: Executing a section of computer code a number of times as part of the program.

Router: Network hardware which forwards packets of data onwards to the most appropriate hardware to which it is connected.

Screencast: A recording of on-screen action that is often accompanied by an audio narration.

Script: A computer program typically executed one line at a time through an interpreter, such as the instructions for a Scratch character.

Selection: A programming construct in which one section of code or another is executed depending on whether a particular condition is met.

Sequence: To place program instructions in order, with each executed one after the other.

Simulation: Using a computer to model the state and behaviour of real-world (or imaginary) systems, including physical or social systems; an integral part of most computer games.

Sprite: A computer graphics object that can be controlled (programmed) independently of other objects or the background.

Uniform Resource Locator (URL): A standard for specifying the location on the internet of certain files.

Variables: A way in which computer programs can store, retrieve or change data, such as a score, the time left, or the user's name.

Web server: A service running on a computer (or sometimes for the computer itself) that returns HTML data for a web page when it receives an HTTP request via the local network or the internet.

World Wide Web: A service provided by computers connected to the internet (web servers), in which pages of hypertext (web pages) are transmitted to users.