Abstraction

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

Abstracting leads to a simple view of the main idea of a thing. It’s about seeing the wood, rather than the trees, or the leaves, or the cells, or the atoms. For example, a fire evacuation plan only shows you what you need to know to get out of a building in an emergency – it does not include the unnecessary details.

“The abstraction process - deciding what details we need to highlight and what details we can ignore - underlies computational thinking”.
Jeanette Wing, 2008

Abstracting often leads to an elegant and simple view of things as the main idea is not shrouded by detail.

Different viewpoints give us different abstractions. World Maps only show the features of significance for their specific audience, a country border based map for government use, a tomographic map for earthquake reporting, a map to learn about physical geography.

Map of the World 1988 By Central Intelligence Agency.[Public domain], via wikimedia Commons
In education, we might use abstraction to create models to teach new ideas, complex or hard to visualise systems. For example, we might use or create a simulation of the solar system, where the order of the planets, their relative sizes and their orbits are represented in a simplified abstraction.

Abstraction is part of our everyday lives, for example, calendars and timetables are created by abstracting time. The complexity of our working week in school is reduced down to a structure of essential features (the timetable). Musical notation is an abstraction of a musical performance. At another level, a programme listing titles, composers and performers is an abstraction of a concert.
Historical periods and events are abstracted at different levels of detail from personal biographies through local, national and global perspectives. For example, Julius Caesar’s personal reflection of his first expedition to Britain provides a very different degree of detail to the broader abstraction of Peter Salway’s Illustrated History of Roman Britain that looks at all aspects of life in Roman Britain.

**Commentarii de Bello Gallico**, an account written by Julius Caesar about his nine years of war in Gaul. (Commentaries on the Gallic War) CC-O

This translation of one section of Book 4 of *Commentaries* on the Gallic War provides a personal summary and abstraction of Caesar’s first expedition to Britain.

Peter Salway’s *Oxford Illustrated History of Roman Britain* looks at all aspects of life in Roman Britain, providing a broader view, a very different degree of detail (abstraction) to Caesar’s personal reflection.

**Why is abstraction important?**

A key element of computing is the complexity of the systems we build. Abstraction provides a means to distil what is essential, giving a manageable approach and framework to create computational solutions.
Abstractions are sometimes represented as layers or hierarchies, allowing us to view things at different degrees of detail. The nature of being able to hide complexity within boxes within boxes makes abstraction a powerful tool as we do not need to worry about the technical detail of what goes on inside each box.

In computer science, we abstract complexity in many ways, such as:

- Computer hardware being seen as components or black boxes. The detail of what goes on inside each component is less important to us.

For example, a computer system can be represented as a simple illustration with no labels, just showing the ‘outside’ of a laptop, this is an abstraction, it is not the real thing.

A simple illustration can represent a computer system.

Or we could draw a simple model of a computer using boxes, a box to represent input devices, a box to represent output devices, a box for the central processor and a box for the memory, what goes on inside each ‘box’ is not considered, just that these components exist and their relationship to each other, this model is an abstraction.

The abstraction above represents a computer. It shows the names of the components and how they interact with each other but hides the complexity of each type of component.

Or we might want to look at very technical information about a computer. A drawing of a circuit board, a part of a computer, is an abstraction, as the detail of how the electrical signals are processed inside the electrical components on the circuit board is hidden.

A technical drawing of part of the raspberry pi showing electrical components and the connections between them.
Image courtesy of [Raspberry Pi Foundation](https://www.raspberrypi.org) (permission requested)
We can create abstractions of a computer system with different degrees of detail, we can include different detail for different purposes.

- Our models of the internet are an abstraction, they hide the complexity of the underlying software and hardware that enable this network to operate. Clicking on a link opens a web page, but another level of detail would look at the packets of data travelling via routers between server and browser, another still would consider the changes in electrical or optical signals in wires and fibre.

- Software is built of layers each hiding the complexity of the next successive layer. For example we might make text bold using the B button on a toolbar, but another level of detail would consider how to implement this in a high-level programming language with a representation of the document, another still would deal with the machine-code implementation of this including the management of binary data in memory or storage.

- Simulations of the physical or social world are computational abstractions: these can be games or to solve real world problems and make better decisions. We might model the physics affecting a racing car in a game, the spread of an epidemic or forecast the weather. In each case only some aspects of the complex, real-world system become part of our computer model.

What does abstraction look like in the primary curriculum?

“[The national curriculum for computing](https://www.gov.uk/government/publications/national-curriculum-for-english) aims to ensure that all pupils: can understand and apply the fundamental principles and concepts of computer science, including abstraction, logic, algorithms and data representation…”

Abstraction lies at the heart of computational thinking and threads itself through activities that involve simplification, summarising and simulation.

When pupils create a story plan, a summary, or work out a mind map they are abstracting, as they are leaving to one side the detail they do not need at that time.

A book report provides a summary, a pupil’s abstraction or view of the book.

A story plan summaries a story, providing an abstraction of the story showing just the key features.
When in Scratch we write the command ‘move 10 steps’, the complexity of the many steps the computer executes in switching on and off pixels on the screen is hidden from us. The command ‘moves 10 steps’ is an abstraction – it is a representation of a more complex thing.

Abstraction lies at the heart of mathematics. Maths might be thought of an abstraction of reality. In primary schools, pupils first learn maths through practical experiences, this is then abstracted to a pictorial representation, then represented through symbols (abstract). For example, a pupil is given a tower of 3 bricks and a tower of 7 is asked how many altogether, then is given a picture with a group of 3 bricks and a group of 7 bricks and again asked how many altogether, and then given a number sentence (equation) to solve of say 3 + 7 = ?

As pupils learn about the complex world they use and make abstractions. For example, pupils learn about properties of materials, ignoring particles, they then find out about particles and ignore atoms and molecules, they then find out about atoms and molecules but ignore electrons and quarks and so on.

The very subjects that pupils study are in fact abstractions. Physics, biology and chemistry capture different levels of detail of the same theme, creating different abstractions to represent the same complex reality. For example, if looking at photosynthesis, a biological abstraction might look at how the plant grows with more or less light, for chemistry we might think about how carbon dioxide and water react to form sugar and oxygen; for physics the interactions between the quantum states of electrons in the component atoms.

Simulations and models are abstractions: these are used across the curriculum to explain ideas. For example, science simulations might help to teach about gravity, history simulations about the Roman invasion of Britain, physical geography models give insights about how fossilization occurs, art simulations might show how to work with clay, data handling models allow exploration of what if scenarios and so on. Also beyond the curriculum simulations and models are the basis of most computer games.

EYFS
In early years, there are many opportunities for pupils to start to summarise. Pupils are asked to recount events and so start to think about what is important and how
to create a summary. When counting they start to sense an understanding of the abstraction of number, as they count three bears, three bricks, three friends and formulate an abstraction of ‘threeness’.

**KS1**

In Key Stage 1, pupils continue to explore abstraction. They start to explore viewpoints in history as they role-play famous people. They study maps in geography learning how to add places of interest and ignore detail. They use world maps and create local maps and so start to see different layers of abstraction. Written forms of abstraction become more common, for example, they abstract in literacy when they create a plan of a story; in science, when they make make notes and charts as they identify what is the most important property of a material to make it suitable for a particular purpose.

In computing lessons, they start to use computer games and simulations and appreciate that they are based on, but simpler than real life, i.e. an abstraction.

**KS2**

In Key Stage 2, pupils continue to simplify and summarise and in so doing become more experienced in abstraction. They reflect on what they know or have learned and create summaries, for example in pre and post topic assessments, recording the most important facts and so creating an abstraction of their understanding. Pupils may start to consider the level of detail in summaries they create. For example, they may add more detail to a story plan as they write.

When presenting reports or arguments, they consider what are the most significant aspects, they summarise their findings in science, they compare geographical aspects over time, and contrast historical events. All these activities require them to consider what are the key points and to manage or ignore what is unimportant; in so doing they are abstracting.

Pupils can look at maps of varying scales as abstractions of the real world. Or they might consider a period in history at global, national, local and even individual levels.

When learning about technical aspects of computers, pupils use abstractions that hide much of the detail, such as when learning about the internet, data representation or algorithms. They learn at a summary level first and then add detail as they look inside the ‘black boxes’ and find out more. They learn to see components of a computer or a system as ‘black boxes’, hiding the underlying complexity.

They may role play the internet, creating an abstraction of this complex network of cables, hardware and software.
When designing games or simulations, pupils include the important detail, but ignore much else. An animation of the water cycle includes only the key steps at ‘big picture’ level, ignoring much of the complexity of the real world.

Pupils use slips of paper to represent the packets of data (red dots) moving around the internet. This is a very simplified abstraction that helps them start to learn about packets, servers and ip addresses.

Pupils create simulations of real world systems, such as the water cycle. They select the most important features and model these

Pupils learn about abstraction as they create animations of complex processes such as dinosaur fossil creation.
A note about abstraction and decomposition
When we are solving problems, abstraction and decomposition often happen without us realising it. We switch between the two ways of thinking. By reflecting more consciously on these processes, pupils can be supported in developing a deeper understanding of both.

In both cases we start with complex situations. With abstraction we bring a better understanding through reducing the complexity (removing the detail) and focus only on that which is necessary.

With decomposition we bring a better understanding through dividing the whole into its component parts. Each component can be further subdivided.

For example, if we were learning about the countries of the world we would use a world map. A world map showing countries is an abstraction. It is reduced to the "countries of the world". (A further abstraction would be a map with only the 7 continents labelled.) But if we were walking the Pennines, a world map would not have insufficient detail to help us. We would need a local map that labels the paths, contours, water and boundaries. There is far more detail because it is needed. A crofter’s map would have even more detail of shelters, hazards to sheep, access routes by quad-bike, etc.

When studying social geography we use decomposition to represent the complexities of human activity, peoples’ government and individual loyalties. One representation might be a gazetteer of countries broken down into sections on, say, population, ethnicity, political affiliation, employment, etc. (such as the https://www.cia.gov/library/publications/the-world-factbook). The more subdivisions of the sections of the data, the more detail is revealed.

Sometimes a summary is helpful, but other times we require detail to better understand something or solve a problem.

Find out more about abstraction

Computational thinking and thinking about computing, Jeanette M Wing, 2008
Wikipedia
Thinking about myself – abstraction
Google games – puzzle
Abstraction, Computational Thinking In Primary Schools, Miles Berry, 2014
Pages 7,8,9 Computer Science: A Curriculum for Schools March 2012
Google Computational Thinking: Abstraction.
Simulations: Zombie Population Clock Simulation Orrery Simulation
Mapping Software e.g. Google Maps - vary the scale, swap into satellite and streetview models. Street Map uses a step change between abstractions to reveal less or more detail, meeting the differing needs of walker through local motorist to national motorist.)