

# Computing

## Communications and Networks Unplugged (Version 1.1)



Lead Author:

**Mark Dorling**

*National CPD Coordinator*

Computing At School

Authoring contributions by:

**Carl Turland**

*Head of Upper School ICT*

Harrow International School Bangkok

Edited by:

**Glyn Barritt**

*Learning Technologies Manager*

SSAT (The Schools Network)

Reviewed by:

**Phil Bagge**

*Advanced Skills Teacher*

*Master Teacher and Regional Coordinator,  
funded by Department for Education*

Computing At School

**Rae Harbird**

*Senior Outreach Fellow*

*Department of Computer Science,  
University College London*

## Abstract:

The aim of this publication is to provide a starting point for teachers looking to understand some of the good ways to go about delivering computing in the landscape of the changes to the English National Curriculum.

It will focus on the breadth and depth of the subject with a focus on Networks and Communications (with links to Data and Data Representation) and an emphasis on understanding how this can be implemented in classrooms whilst taking into account progression through Primary education (aged 7 to 11) into lower secondary education (aged 11 onwards).

The English National Curriculum for Computing is made up of three separate but interdependent strands: Computer Science, Information Technology and Digital Literacy. Each component is essential in preparing pupils to thrive in an increasingly digital world.

The following explanations of the three strands of Computing are adapted from the Computing At School Primary and Secondary Guidance documents:

**Computer Science (CS)** is the *foundations*; it is concerned with how computers work and how to make them do things. This does include programming but there is a rich breadth and depth of subject knowledge, some of which is detailed in their publication.

**Information Technology (IT)** is the *applications*; this is concerned with using applications to solve real-world problems and express creativity. Pupils should be challenged to use a variety of tools to create digital artefacts, that is, items such as text, pictures, music or animations created through the use of digital technologies.

**Digital Literacy (DL)** is the *implications*; this is concerned with making pupils effective, responsible and critical users of technology within a wider society. The modern world comes with a range of new threats to people's health and security, making your pupils digitally literate will prepare them to take an active role in the modern world.

Miles Berry & Peter Kemp, 2013

Although, the English 2014 National Curriculum Computing curriculum has three strands, it is essential that pupils through Primary school and until they leave lower Secondary education (aged 11 - 14), they should see the three strands of Computing (CS, IT and DL) as one single subject of Computing, only at upper secondary (aged 15 and 16) when taking qualifications should the pupils see them as explicit subjects. Therefore, it is crucial that pupils receive a balanced curriculum throughout Primary and Secondary education, one in which provides pupils with a secure foundation for further studies in computer science, information technology and/or digital media qualification.

With this in mind, this publication will try and emphasise the dependences between the three strands, and where ever possible draw out the application of information technology and consider

the implications through digital literacy, when laying the foundations of computer science.

This work has been carried out as part of the Digital Schoolhouse (DSH) accelerated learning model. They were developed through the project's passion to identify and deliver more engaging ways of teaching the CS and IT principles and concepts which were often presented to pupils in an unconnected or unimaginative manner. These lessons are also regularly taught to pupils in both primary and secondary education in the Borough of Slough (and surrounding areas). For more information on the internationally recognised Digital Schoolhouse project, please visit: [www.digitalschoolhouse.org.uk](http://www.digitalschoolhouse.org.uk)

## Digital Schoolhouse Project

This work was carried out as part of the Digital Schoolhouse (DSH) accelerated learning model and reflects the project's aim to identify and implement more engaging ways of teaching the principles and concepts of CS and IT, so often presented to pupils in an unconnected or bland manner. Lessons were taught regularly to pupils in both primary and secondary schools in the Borough of Slough and surrounding areas.



DSH was originally supported by SSAT (The Schools Network) through its Leading Edge network (which brings together high performing schools seeking challenge and mutual support); indeed, DSH is a great example of the four main tenets of SSAT's mission:

- **Inquire:** what class based action research and teacher-led inquiry has raised standards?
- **Innovate:** how have schools done things differently in order to do them better?
- **Inspire:** how have schools influenced each other's work through our network?
- **Impact:** what changes have been proven to make a difference to student outcomes?

SSAT funding support enabled DSH to respond to the feedback received from primary and secondary schools on transitional and curriculum challenges. With a focus on the teaching of Information Technology (IT) and Computer Science (CS), the project also introduced Digital Literacy (DL) across a creative curriculum. (This approach was later recognised and commended in the Royal Society report *Shut down or restart, published in January 2012* and won the Times Educational Supplement (TES) award for ICT in 2013). The aim of DSH lessons is to accelerate pupils' learning of new skills and concepts with a focus on how they are deployed in secondary education and the world of work/business.

*For more information on the internationally recognised DSH, please visit [www.digitalschoolhouse.org.uk](http://www.digitalschoolhouse.org.uk); and for SSAT (The Schools Network) - [www.ssatuk.co.uk](http://www.ssatuk.co.uk)*

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## Testimonials

### Class teacher feedback

*"Pupils from Slough had a wonderfully 'mind-expanding' day at the Digital Schoolhouse. Our topic of study was 'The World and travel' this term so we chose the day on the World Wide Web and discovered how information travels on the internet around the world. Mr Dorling related each area of computer science to simple analogies that the primary aged pupils could relate to, such as post-codes for IP addresses. The knack the DSH project has is getting the pupils to wrestle with complicated concepts while they think they are 'playing around' in games about computers or on the computers themselves, which is truly phenomenal. The pupils understanding increases exponentially and each child is challenged and motivated throughout the day. To have the DSH located in a the secondary school is the icing on the cake because the primary aged pupils, from the cluster of neighbouring primaries, experience the secondary phase, and this, I am sure, does much to enhance transition for these pupils too. We will be returning next term!"*

Gill Howarth  
Head teacher, DWS

### Primary school pupil feedback

*"At Digital Schoolhouse I learnt about the internet and how it works. I felt very excited because I was looking forward to that day. I have learnt a lot during the day, for example every website has an IP address, which means Internet Protocol (this is used to communicate data). I also really enjoyed learning about how a search engine works. Finally, I would like to say that I really enjoyed my day at Digital Schoolhouse and I hope I will come here again sometime."*

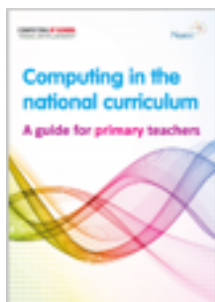
Syed  
Aged 10

*"I really liked learning about the internet and how it works. I thought that the activities and games were really fun and it made us think hard about what we were learning. I found understanding how the internet works and relating it to how the four libraries/servers work together to give me the documents I want on the internet. I look forward to coming back and learning some more about the internet."*

Molly  
Aged 9

## Getting started

Computing At School (CAS) and Naace have written a short guide for primary teachers, to help them demystify the programme of study for primary schools.



It is designed to help teachers with getting to grips with the new requirements quickly and to build on their current practice. The Progression Pathways Assessment Framework is aligned (developed CAS) to the Primary Guidance document, and the activities and progression have also been mapped to these documents for ease of use. To obtain your free copy of the Primary guidance, please visit: <http://www.computingschool.org.uk/data/uploads/CASPrimaryComputing.pdf>

## National Curriculum coverage

This publication will be focusing on the programme of study for Key Stage 2, bullet points 4 and 5, and Key Stage 3, bullet points 4 also. The activities will be structured and ordered in line with the national curriculum programme of study (PoS) content.

### Key Stage 2 (aged 7 - 11)

- “understand computer networks, including the internet; how they can provide multiple services, such as the World Wide Web, and the opportunities they offer for communication and collaboration”
- “use search technologies effectively, appreciate how results are selected and ranked, and be discerning in evaluating digital content”

### Key Stage 3 (aged 11 - 14)

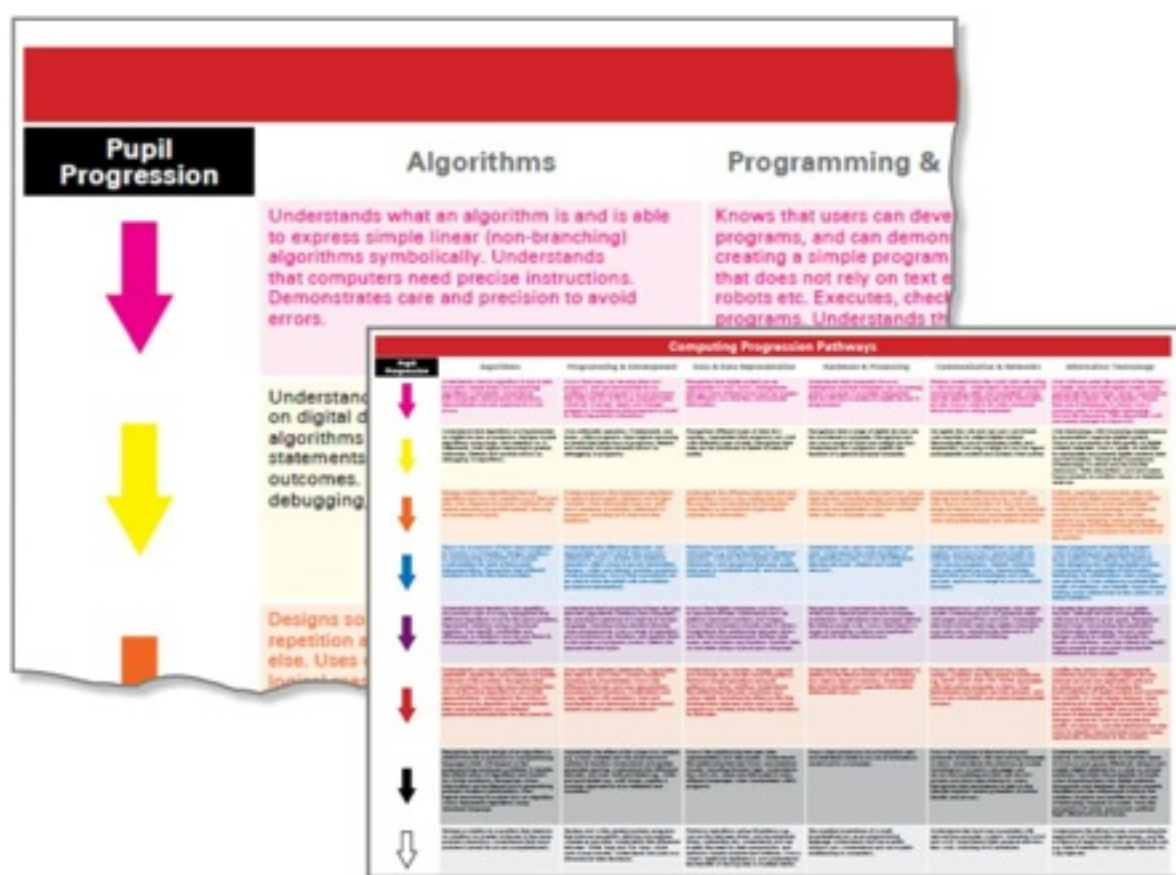
- “understand simple Boolean logic [for example, AND, OR and NOT] and some of its uses in circuits and programming; understand how numbers can be represented in binary, and be able to carry out simple operations on binary numbers [for example, binary addition, and conversion between binary and decimal]”

Please note that we have included the bullet point from Key Stage 3 because the National Curriculum is the minimum entitlement for pupils. By covering some of the content at Key Stage 3, it is the lead author’s experience that the pupils learning of Key Stage 2 content is enriched, and as a result their understanding of the concepts and principles become much deeper and more meaningful!

## Evidencing progression

The activities in this publication have been aligned to both the English National Curriculum 2014 and to the highly popular Progression Pathways Assessment Framework published by Computing at School. To download your free copy of this Assessment Framework and explanation of how the Assessment Framework works, please visit:

<http://community.computingschool.org.uk/resources/1692>



This publication also maps the Primary Guidance document published by Computing At School and Naace to the Computing At Schools Progression Pathways Assessment Framework Assessment. The aim of doing this is to assist the reader with understanding what progression in Computing may look like.



## PoS 2.4 & Primary Guidance

**Computer networks**, including the internet, are made up of computers connected together. The computers include fast, dedicated machines that pass on data that's not intended for them (called 'routers', 'gateways', 'hubs' or 'switches', depending on particular roles), and 'servers' (always-on machines looking after emails, web pages and files that other computers might ask for from time to time). The connections between the computers in a network may consist of radio or satellite signals, copper wires or fibre-optic cables.

Information stored on computers and information travelling over networks must be digitised (i.e. represented as numerical data). The computer network in your school and the internet use the same method or 'protocol' to send and receive this data. The data is broken up into small 'packets', each with identifying information, which includes the IP (internet protocol) address of the sender and recipient.

These packets of information make their way across the internet from source to recipient. At the far end, the packets get stitched back together in the right order and the email is delivered, the website is accessed, or the Skype call gets connected. Many of these packets, travelling at near light-speed, are generated by web servers returning web pages to the browser requesting them.

By connecting people around the world and passing on packets of data from sender to recipient, the internet has created many opportunities. These range from communication (such as email, video conferencing, blogs, forums, social networks) and collaboration, such as wikis (including Wikipedia), to real-time collaborative editing, Creative Commons media (permission to share and use creative work with conditions stated by the creator) and open-source software, which is available for us to use and change.

### Communications & Networks: Red

"Know the names of hardware e.g. hubs, routers, switches."

### Communications & Networks: Orange

"Understand the difference between the internet and internet services e.g. world wide web."

### Hardware & Processing: Blue

"Knows the difference between physical, wireless and mobile networks."

### Data & Data Representation: Purple

"Know that digital computers use binary to represent data. Understands how bit patterns represent numbers and images."

### Data & Data Representation: Purple

"Knows that computers transfer data in binary."

### Communications & Networks: Purple

"Understands data transmission between digital computers over networks, including the internet i.e. IP addresses and packet switching."

### Communications & Networks: Red

"Know the... names of protocols e.g. ... TCP/IP"

### Communications & Networks: Purple

"Understands data transmission between digital computers over networks, including the internet i.e. IP addresses and packet switching."

### Information Technology: Orange

"Creates digital content to achieve a given goal through combining software packages and internet services to communicate with a wider audience e.g. blogging."

### Information Technology: Blue

"Understands the potential of information technology for collaboration when computers are networked."



# PoS 2.5 & Primary Guidance

Using search technologies involves aspects of computer science, information technology and digital literacy. Effective use of search engines gets the results you want. It relies on specifying the right keyword, skimming and scanning the results to see which seems most relevant, and distinguishing between the main results and adverts presented as sponsored results. It may also involve using other features<sup>7</sup> of the search engine, including searching for phrases rather than keywords, or limiting searches to a particular time frame, language, reading level or website.

**Communications & Networks: Yellow**

"Navigates the web and can carry out simple web searches to collect digital content."

**Data & Data Representation: Orange**

"Uses filters or can perform single criteria searches for information."

**Information Technology: Yellow**

"Shows an awareness for the quality of digital content collected."

**Data & Data Representation: Blue**

"Performs more complex searches for information e.g. using Boolean and relational operators."

In order to return results, search engines use 'web crawler' programs. These programs visit the pages of the web, follow the links they find and can make a copy of each page visited. The pages are indexed, keeping track of keywords on each page. When you enter a search query, the search engine returns pages from its index on which your keyword(s) or phrase appears.

**Communications & Networks: Blue**

"knows how search results are selected, including that search engines use 'web crawler programs'"

Search engines take many factors into account. At the heart of Google's algorithms<sup>8</sup> is 'PageRank', which determines the quality and rank of a page based on the quality of the pages that link to it. Their quality is, in turn, determined by the quality of the pages that link to them, and so on.

**Communications & Networks: Purple**

"Understands how search engines rank search results."

Just because a page has a high rank in Google or another search engine for a particular query, it doesn't mean that the content is true, age-appropriate or relevant to a particular project. Pupils need to develop skills in evaluating digital content, including how trustworthy the information is (perhaps by verifying it with another independent source), whether it's something that the audience for a project would be able to grasp, and why the content was posted in the first place (e.g. to give a balanced overview, or simply to advance one side of an argument).

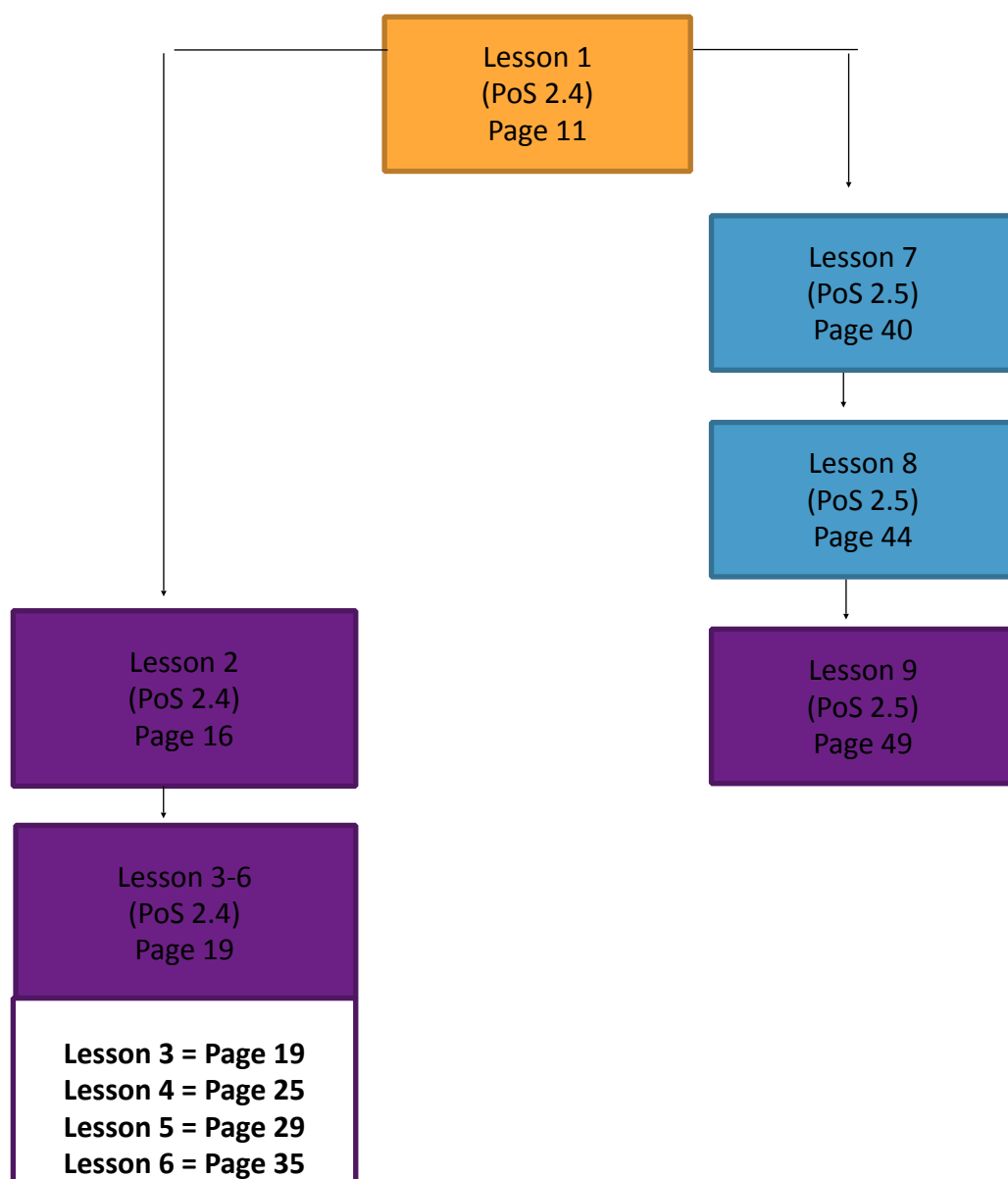
**Information Technology: Red**

"evaluates the trustworthiness of digital content and considers the usability of visual design features when designing and creating digital artifacts for a known audience."

## Delivery order of the activities

Some of the activities in this publication are more complex than others and come in later in the key stage. Therefore, the author is not suggesting that you teach the activities in the order that they are presented in this publication. They are currently organised by progression within the National Curriculum programme of study.

The author believes that it would be a much better approach to teach the content in the order of the colours in Progression Pathways Assessment Framework as the interdependences between concepts and principles will become much clearer to both the class teacher and the pupils.



## Networks & Communications unplugged

### 1 Difference between the Internet and World Wide Web

#### **Summary:**

This short activity will help pupils understand the difference between the internet and World Wide Web.

#### **National Curriculum PoS:**

- Key Stage 2
  - Bullet point 4
  - *“understand computer networks, including the internet; how they can provide multiple services, such as the World Wide Web, and the opportunities they offer for communication and collaboration”*

#### **Progression Pathways:**

- Networks & Communication: Orange
  - *“Understands the difference between the internet and internet service e.g. World Wide Web. “*
  - *“Shows an awareness of and can use a range of internet services e.g. VOIP.”*

#### **Cross curriculum links:**

- Literacy
- Citizenship

#### **Age group:**

- years up to 7 (years 4 - 6 in primary school)

#### **Materials:**

- Interactive white board or chalk board
- Large classroom or school hall
- Possibly access to a school or public library

#### **Introduction:**

A **server** is a computer that is connected to other computers and possibly the internet. It deals with the security relating to files on the computers and handles access rights to them.

A **client** is a computer system that uses a service offered by a server usually by way of a computer network.

**Servers** are like libraries, the **clients** are people who visit the library. Clients request access (borrow) to artefacts such as books, when people want to access digital documents from a server, they typically do so using a client **web browser**.

We can think of the Internet like a giant network of inter-connecting libraries, built from lots of **servers** and clients accessing a range of services available. Therefore, the Internet is the biggest **network** of all. These networks all use the same rules which allow documents to travel between servers all over the world and billions of computer users.

The **World Wide Web** is more commonly known as the web. When we use a web browser we used the abbreviation “www.” in the address bar. The web is the system of interlinked documents stored on servers. These documents are most commonly accessed via a web browser e.g. Google Chrome, Internet Explorer, or Mozilla Firefox. Documents may contain text, images, videos, and other multimedia, and navigate between them via hyperlinks.

### How could I teach this in my classroom?

#### New vocabulary:

- Client
- Internet
- World Wide Web
- Server

#### Instructions:

Begin the lesson by identifying if the pupils understand what the following words mean, and if they see a difference between them.

- Internet
- World Wide Web

The teacher will often find that the pupils will use the same definitions for both and will consider them to be the same thing, which provides excellent learning opportunities.

The class teacher should ask the pupils if they have ever been to a public library. All the pupils should reply “yes”. Ask them in pairs or small groups to list all the different services can obtain in the library and types of things you can loan.

The pupils will come up with the obvious items, such as books and newspapers but others will consider things such as video and audio. The young pupils may struggle with the services that are available e.g. use of internet, story time, and community chat areas.

The class teacher should then present the pupils with a THUNK (a question that doesn't necessarily have a correct answer): “If I were to move all the books from the library and move them to another building, where is the library”<sup>1</sup>, see figure 1 above:



**Figure 1: THUNK question**

If the pupils believe that the building is the library then it will not have moved. However, if the pupils believe that the items and services within the building are what make a library then it will have moved.

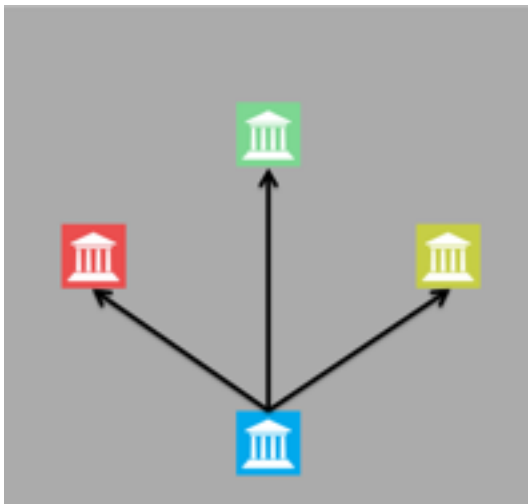
With this discussion in mind, the class teacher is able to consider how the library system works and relate this back to the difference between the internet and World Wide Web. Begin this teaching by asking the pupils how they loan a book from the library. Ask them to describe the process. The teacher has found that pupils will always describe a process where the library has the book in stock.

Challenge the pupils by asking them what if they want an item from the library that isn't in stock or isn't stocked at the particular library. Some pupils will be aware of the process, that is, one library will look for the item by search for it at neighbouring libraries. When the book is found to be in stock, it is requested and transported by van to the library and then the library user is then informed that it is ready for collection. Ask the pupils how long this process takes. If they don't know, encourage them to take a visit to the library to find out!

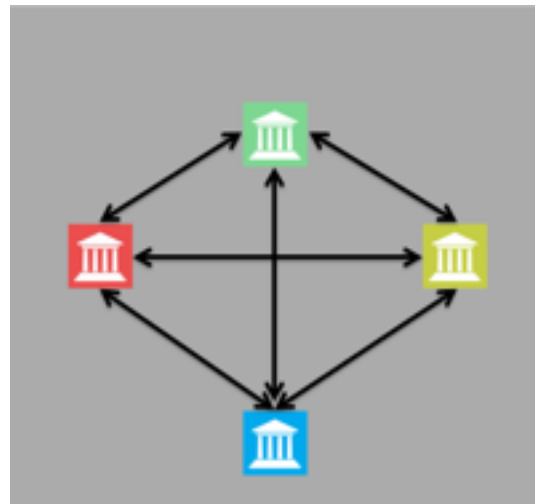
Model the process on the classroom white board where one library may request items from many libraries, the pupils should draw a diagram, see figure 2a below. Ask the pupils what happens if one of those other libraries receives a request from a user for an item that isn't stocked, the pupils will say that they will also search and request the item from other libraries. The pupils should then add links between all the libraries showing how the items can flow between the libraries, see figure 2b. It is the author's experience that prior to the lesson, the class teacher should learn the names of four local libraries that the pupils might have visited to give it a local feel.

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<sup>1</sup> Gilbert. I, The Little Book of THUNKS, Crown House Publishing Limited, 2007



**Figure 2a: One request**



**Figure 2b: Multiple requests**

To help the pupils grasp the ideas above, you can either perform a human internet activity. Begin the activity asking the pupils what the word “server” means. The experience of the authors is that they will probably relate it to a servant i.e. someone who brings you things, or a lunch time supervisor who manages the food in the lunch hall.

Split the class in to small groups and give each group a name e.g. server 1. Distribute the pupils in the classroom or school hall. Give each group of pupils a pile of books from the school library and place them on a table. Create a set of instruction cards that request a particular book from a particular group of pupils i.e. a server. The table is the server, the books are the documents being transported on the Internet, and the pupils fetch and return the books for the client. Then give the pupils instructions, each child in the group takes it in turn to fetch and return their item listed on the card. To prevent the items simply swapping tables, explain to the pupils that they can only borrow a certain number of items at any one time. Therefore, the pupil who requested (collected) the item, has to return it to the original server before the group requests the next book.

To make this game more fun, you can turn it into a quiz. When the item has been collected you can ask them for a specific piece of information like 2<sup>nd</sup> word, third paragraph, page 72 (which sets up the next lesson’s activity nicely on finding information on a page). When you put many of these clues together you uncover a secret message! By asking the pupils previously to return the items when finished you can do this activity as a race.

After completing the activity, refer the pupils back to the THINK question about the books in the library. The pupils will likely now say that the items in the library i.e. the knowledge or artefacts, is what make a library. This provides you with the opportunity to relate this understanding to the digital artefacts i.e. the images, video, audio and documents on the internet being the World Wide Web, with the library buildings and networks i.e. vans, for transferring the artefacts between libraries can likened to the internet, and the libraries as the servers. With the artefacts within the libraries (servers) being the World Wide Web. It is the author’s experience that it is nice to get the pupils to produce visual representations of the key vocabulary (networks, servers and World Wide

Web) from the lesson and produce wall displays from them combined with figure 2b above. See figure 2c below:



*Library = Server*



*Books = World Wide Web (WWW)*



*Library user = client*



*Network = Van*

**Figure 2c: Example wall display**

If the pupils were able to come up with services available in the library, it is worth discussing with them that they are not the items i.e. books, but standalone services also offered by the library. Therefore, when using the internet (like the library) you can use things such as Voice over internet (VOIP) e.g. Skype, and email which work through the internet but are not the World Wide Web.



## 2 Understanding how data travel through the internet

### **Summary:**

This lesson will help pupils to understand how the internet is structured and the free flow of data i.e. no one route. It will also prepare pupils for the next lesson on understanding how data transfer works over networks, including the internet.

### **National Curriculum PoS:**

- Key Stage 2
  - Bullet point 4
  - *“understand computer networks, including the internet; how they can provide multiple services, such as the World Wide Web, and the opportunities they offer for communication and collaboration”*

### **Progression Pathways:**

- Networks & Communication: Purple
  - *“Understands data transmission between digital computers over networks, including the internet i.e. IP addresses and packet switching.”*

### **Cross curriculum links:**

- all

### **Age group:**

- 8 years up

### **Materials:**

- large classroom
- Print out of tube map (Appendix 1)

### **Introduction:**

The main purpose of the Internet is to make sure that two devices that want to share information can find each other, regardless of how far from each other they are in the real world and regardless of how busy they are. It is called a ‘network of networks’ because without the Internet a computer can only talk to the computers around it, in the same room or organisation.

## How could I teach this in my classroom?

### New vocabulary:

- Internet
- Network
- World wide web
- Server

### Instructions:

Begin the lesson by show pupils a picture of a underground system i.e. London Underground is useful as it contains lots of connecting stations, use only a small portion of the map for the activity, see figure 3 below.



Figure: 3 Tube map

The class teacher should ask the pupils to imagine that they were travelling across London on a day out. Give the pupils a station to start from. Then give them a destination station and ask them to calculate a route from the first station to the second. With experience, the class teacher will find that many of the pupils will come up with different routes. As an extension activity the pupils can use the <http://traintimes.org.uk/map/tube/> to illustrate what they have been doing.

The class teacher should repeat the tube map activity but close one of the stations' or lines between the stations on one of the more popular routes generated by the pupils. In a discussion after repeating the activity, ask the pupils to identify the strategies they used for overcoming the problem. The class teacher will find that the pupils will simply take different routes around the closed station. Finally, the class teacher should then liken the tube journey to how a file travels through the Internet (network of networks), with the stations on the tube map being servers.

**Extension Activity:**

A further activity that can be carried out to demonstrate how packets are transferred over a network works requires the following equipment:

- String (cut into metre strips)
- Empty toilet or kitchen paper roll

Before the lesson, tie the string together into a star shape (so it will form a star topology) with 4-6 points to the star. Get a pupil to hold onto each of the ends with another pupil stood at the middle of the star. Each pupil at the end should take it in turns to pass their empty toilet roll ('packet') down their string to the middle pupil who acts as the switch/hub who then passes out another toilet roll packet to the intended recipient (pupils holding the string).

This activity can then be extended to show how the internet is formed by linking the different star (topologies) groups together using a longer piece of string, this helps to demonstrate that the internet is a "network of networks".

This activity can also be repeated in lesson 5 of this publication when using postcodes and IP addresses with each part of the star being allocated a separate postcode/IP address.

Furthermore, you can also teach pupils in secondary school the difference between private and public IP addresses. This would work with the introduction of another pupil at the point where the long piece of string connects one network to another. They would act as a router and would show their public IP address to the other networks but the pupils within that group would have a private IP address that only can be seen inside that network.

### 3 Data transfer protocols

#### **Summary:**

This short activity will help pupils begin to understand how networks work; in particular, data transfer protocols. The pupils will do this by creating their own data transfer protocol using a string of binary (bit patterns).

#### **National Curriculum PoS:**

- Key Stage 2
  - Bullet point 4
  - *“understand computer networks, including the internet; how they can provide multiple services, such as the World Wide Web, and the opportunities they offer for communication and collaboration”*
- Key Stage 3
  - Bullet point 4
  - *“understand simple Boolean logic [for example, AND, OR and NOT] and some of its uses in circuits and programming; understand how numbers can be represented in binary, and be able to carry out simple operations on binary numbers [for example, binary addition, and conversion between binary and decimal]”*

#### **Progression Pathways:**

- Data & Data Representation: Purple
  - *“Know that digital computers use binary to represent data. Understands how bit patterns represent numbers and images.”*
  - *“Know that computers transfer data in binary”*
- Networks & Communication: Purple
  - *“Understands data transmission between digital computers over networks, including the internet i.e. IP addresses and packet switching.”*

#### **Cross curriculum links:**

- Maths
- Science

### Age group:

- 9 years up

### Materials:

- Interactive white board or chalk board
- Large classroom or school hall
- Work sheets for converting denary to binary (Appendix 2)

### Introduction:

- A **protocol** is a standard set of rules and instructions to be followed by a computer when sending and receiving messages from other computers.
- A computer that sends a message to another computer is known as the **sender**.
- A computer that receives a message from another computer is known as the **receiver**.
- A number system based on the number ten is known as **decimal**. It uses ten different numbers 0 to 9.
- A number system based on two numbers is known as **binary**. It uses two different numbers 0 and 1.

### How could I teach this in my classroom?

### New vocabulary:

- Network
- Protocol
- Binary
- Decimal
- Morse code

### **Instructions:**

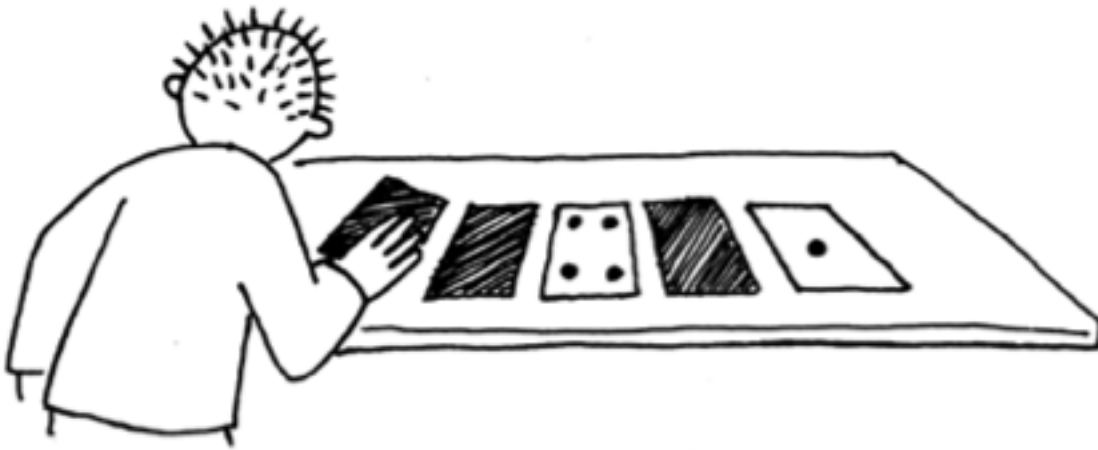
The decimal number system, also known as base 10, is used by modern civilisations mainly because we have 10 fingers. It is known as base 10 because there are 10 different number values from 0 to 9, which allow us to make an infinite number of combinations.

At school you have learnt how to use the decimal number system by using Thousands, Hundreds, Tens and Units. The teacher should, after recapping on the decimal number system, begin this lesson by helping the pupils to understand binary counting. The first task is to complete table 1 below to help build confidence in the pupils in the Base 10 (decimal) number system:

| Number |  | H | T | U |
|--------|--|---|---|---|
| 99     |  | 0 | 9 | 9 |
|        |  | 1 | 5 | 6 |
| 7      |  |   |   |   |
| 56     |  |   |   |   |
|        |  | 0 | 0 | 9 |
| 111    |  |   |   |   |
| 180    |  |   |   |   |
|        |  | 2 | 2 | 3 |
| 23     |  |   |   |   |
|        |  | 1 | 4 | 8 |
| 255    |  |   |   |   |

**Table 1: Counting in Base 10 (decimal/denary) number system**

Computers only use zero and one to make the same numbers. Since computers are electronic devices, it is easy to tell the difference between high voltage and low voltage i.e. on and off. We use high voltage to represent 1 and low voltage to represent 0. Using just the two values, 1 and 0, to represent numbers is known as binary or Base 2, with each 1 or 0 being known as a bit. There are some really fantastic activities available from CS Unplugged for doing this: (<http://csunplugged.org/binary-numbers>), see the binary counting illustration below in figure 4a:



**Figure: 4a CS Unplugged binary counting illustration**

Once the pupils have learnt about the Base 2 (binary) number system. They should consolidate this learning by completing table 2 below:

| Number |  | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|--------|--|-----|----|----|----|---|---|---|---|
| 146    |  | 1   | 0  | 0  | 1  | 0 | 0 | 1 | 0 |
|        |  | 0   | 0  | 0  | 0  | 0 | 0 | 1 | 1 |
| 5      |  |     |    |    |    |   |   |   |   |
| 24     |  |     |    |    |    |   |   |   |   |
|        |  | 0   | 1  | 0  | 0  | 0 | 0 | 0 | 1 |
| 93     |  |     |    |    |    |   |   |   |   |
| 131    |  |     |    |    |    |   |   |   |   |
|        |  | 1   | 0  | 1  | 1  | 1 | 0 | 0 | 0 |
| 255    |  |     |    |    |    |   |   |   |   |

**Table 2: Counting in Base 2 (binary) number system**



When the pupils are confident with binary counting you can progress the learning to begin investigating data transfer protocols.

The following activities will help pupils to understand that all data in a computer must be represented in binary, so anything that is to be processed or transferred between computers must first be converted into a series of 1's and 0's. This means everything, including words, sounds and images, must be converted to binary for the computer to use it.

The pupils should preferably use electrical light circuits or torches to transfer the bit patterns for the decimal numbers in the table above. The class teacher should not instruct, nor guide the pupils on how to complete the task of transferring the data. Pupils should be placed in pairs, both with a simple circuit with bulb or a torch. It is important that the pupils invent and agree the rules for transferring the bit patterns i.e. they need to decide what represents a '1' and '0'. Identifying the '1' and '0' will only get the pupils so far, the missing element that is needed in any transfer protocol is time i.e. how long the light is on or off for, and the length of the pause between transferring bits e.g. the transfer of a bit is on the tick of the clock. The questioning of the class teacher is key to achieving this. See figure 4b for details:

The teacher should ask the pupils; what if they couldn't communicate with the sender/receiver to know when he or she is ready? This will encourage the pupils to think about how the sender signals to the receiver that they are ready to transmit the bit pattern and when the transmission is finalised, likewise the receiver.



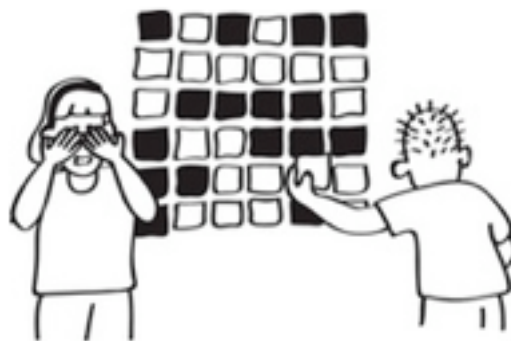
**Figure 4b: Simple circuits.**

Conclude this unplugged activity by asking the pupils to transfer more than one number in a single message e.g. 7, 8, 4, 3, 5. i.e. a really long string of 1's and 0's This will result in pupils having to transfer 8 bits multiplied by 5 numbers which equals 40 bits. Many of the pupils will struggle to do this. Some pupils will split the 40 bits into smaller and more manageable chunks or groups, called

“packets”. It is important that the pupils consider the scalability of this solution? What if they were transferring hundreds of numbers per message would it be practical to turn the numbers into a single decimal number?

Investigate other types of data transfer methods from history. For example, electronic circuits can be used to send messages. In 1836 Samuel Morse, Joseph Henry and Alfred Vail invented a method of sending messages using a simple on/off system known as Morse code. The code is based on the length of time the circuit is switched on for, and uses long and short signals to represent the letters in the alphabet. A short press on the key is called a dot and a long press a dash. For example, ‘dot dot dot dash dash dash dot dot dot’ is the internationally-recognised distress signal, SOS. If less able pupils are struggling with the previous described activity then it is worth asking them how they could generalise the Morse code solution to their problem i.e. 1 is a dot and 0 could be a dash.

This lesson has provided an excellent foundation for learning about packet switching later in this publication, but also the concept of parity bits (which should be covered during Key Stage 3) which is available from the CS Unplugged website: (<http://csunplugged.org/error-detection>), See figure 4c for the error detection illustration. It is the author’s experience that pupils in primary education love this activity and is well worth spending some class time learning.



**Figure: 4c CS Unplugged error detection illustration**

## 4 Packet switching

### **Summary:**

Using pupils understanding of data transfer and introduction to packet switching, pupils will perform a role play of how the internet works. The aim of this is to consolidate what has been learnt in lesson 2 and 3. If pupils didn't work out independently about packets of data from the last lesson then this should be regarded as an introduction. The foundation from this lesson will then be developed further in the next lesson to cover IP addresses.

### **National Curriculum PoS:**

- Key Stage 2
  - Bullet point 4
  - *"understand computer networks, including the internet; how they can provide multiple services, such as the World Wide Web, and the opportunities they offer for communication and collaboration"*

### **Progression Pathways:**

- Networks & Communication: Purple
- *"Understands data transmission between digital computers over networks, including the internet i.e. IP addresses and packet switching."*

### **Cross curriculum links:**

- all

### **Age group:**

- 9 years up

### **Materials:**

- large classroom
- Print outs of emails or pictures (Appendix 3)
- Envelopes

### **Introduction:**

#### **Packet Switching**

Packet switching is the process of dividing the information into smaller 'packets' before sending them over the network. These packets may not follow the same route to get to their destination, but when they do, they are recompiled back into the original data.

## How could I teach this in my classroom?

### **New vocabulary:**

- Internet
- Server
- Packets
- Packet switching

### **Instructions**

The activities described in this lesson plan will take two or possibly three lessons to complete.

The teacher should begin this series of lessons by watching the video “A Packets Tale” ([https://www.youtube.com/watch?v=ewrBaIT\\_eBM](https://www.youtube.com/watch?v=ewrBaIT_eBM)) and then map the journey to get a web page from their home to a webserver and back again via a Prezi animation from code-it.co.uk.

Animation:

[http://prezi.com/v7mm9\\_wuxizf/?utm\\_campaign=share&utm\\_medium=copy&rc=ex0share](http://prezi.com/v7mm9_wuxizf/?utm_campaign=share&utm_medium=copy&rc=ex0share)

Animation Teacher Notes:

<http://code-it.co.uk/internet/connectingtheinternet.pdf>

Continue the second lesson by explaining to the class that they are going to do an internet role play. They should ask the pupils to stand randomly around the room like the tube map activity from lesson 2. The class teacher should then liken the tube journey to how a file travels through the Internet with the stations being servers.

Like with the tube map activity, choose a pupil to be the start of the journey and another to be the destination. Give the pupils an envelope with a file in it i.e. email or web page. Ask the class to pass the message from the start to the destination.

The class teacher should cut a picture or email into six pieces, and then place some random binary strings e.g. 100100101, on each of the pieces of paper to illustrate the chunking from last lesson. Place each piece into as many envelopes. This time when you choose the start and destination points, write the pupils' names on the envelopes.

Ask the class to pass the packets from the start to the destination. From experience the pupils will tend to pass the envelopes randomly through the internet, especially if they all are both source and destinations. If the pupils don't, then encourage them to do so.

When the envelopes arrive at the destination ask the pupils to reassemble the picture or the web page. Explain to the pupils that each of the envelopes is called a packet and by passing them through the internet it is called packet switching.

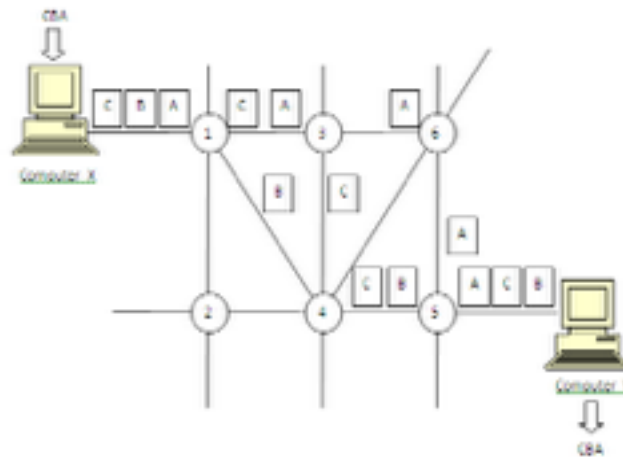
It is important for the teacher to ask the pupils how they knew whether or not to keep the packet? The pupils will answer that they only kept the packet if there name was on it, otherwise they simply passed it randomly in any direction on to the server next to them and waited to be passed the next packet. It is the author's experience that pupils will often read the name on the packets and pass them in the general direction of that pupil. If this happens, don't worry, because when the pupils repeat this activity in later lessons when they will be uniquely identified by an internet protocol (IP) number they will get a more realistic understanding of what happens.

Repeat the second unplugged activity but this time remove and tear up one of the packets during the file transfer between pupils. Ask the pupils to reassemble the message which will not be complete. Ask the pupils how they know which packet is missing? Ask them to consider how they could easily identify in future how to overcome this problem? If the pupils struggle to identify the missing packet and come up with the idea of giving each packet numbers i.e. 1 of 6. Then repeat the unplugged activity but this time get half the class to put packet numbers on the envelopes and the other half not.

Ask the pupils to think about what they should do if one of the packets doesn't arrive? They usually come up with the idea that the entire message is retransferred i.e. another copy of the file is cut up into six parts and placed in envelopes or the data from the missing packet is transferred again i.e. you need to cut out just the piece of the missing file and place it in the envelope to resend.

At this point, it is important to relate this learning back to the explanation of the library system from the first lesson. Each of the stations on the tube map, like each of the pupils in the game, is a server. The packets containing the parts (like chapters in a book, with each chapter transported in the vans separately) of the file are passed from source to destination through the servers that are all connected together.

On a white board record where in the classroom each of the pupils where standing. Then ask them to collectively draw the route through the human internet of each packet like in figure 5 below:



**Figure 5: Packet switching through the human internet**

### **Extension Activity:**

An extension activity can be carried out here to cover an aspect of digital literacy i.e. persistency of data and your digital finger print. The materials you will need are:

- A ball of wool (glitter wool if possible)
- Glitter

It is best carried out in a large area like a sports hall or playground. Pupils randomly stand around the area and one pupil is given the ball of wool. This pupil is considered to have posted digital content online; it may be a Facebook post, a tweet, an Instagram photo or a Snapchat. They then throw the ball of wool to another pupil whilst keeping hold of the end so it creates a trail. This then continues with the pupil throwing the wool to another pupil (sharing or retweeting the content) whilst holding on to the trail.

Do this a number of times and then go between the first and second pupil and cut the line of wool between them and take the wool from the first pupil. Ask the pupils what they think this represents, you are looking for the pupils to say that the person has now deleted the original content they posted and then ask them if the content has now been removed from the entire internet. The pupils should say no because there are still a number of pupils holding wool. The content has been shared a number of times creating numerous copies. Therefore, the discussion should be focused on just because a version has been deleted it does not mean it now does not exist.

If you are using a ball of glitter wool you can also use this to show that even though the pupil has deleted the content, they still have glitter on their hands – a digital fingerprint that reveals information about them and the content they posted.

## 5 Understanding IP Addresses as unique identifiers

### **Summary:**

In this lesson, pupils will develop an understanding that computers on networks have a unique identifier called an IP address to enable data packets to reach their destination. This activity provides pupils with the foundation they need to learn about the structure of IP addresses.

### **National Curriculum PoS:**

- Key Stage 2
  - Bullet point 4
  - *“understand computer networks, including the internet; how they can provide multiple services, such as the World Wide Web, and the opportunities they offer for communication and collaboration”*

### **Progression Pathways:**

- Networks & Communication: Purple
  - *“Understands data transmission between digital computers over networks, including the internet i.e. IP addresses and packet switching.”*

### **Cross curriculum links:**

- Geography

### **Age group:**

- 9 upwards

### **Materials:**

- Envelopes
- Paper
- Pencils
- Access to a web browser
- Interactive white board
- Possible access to command prompt
- Print-out of Postcodes (Appendix 4)
- Print-out of IP addresses (Appendix 5) **or** IP Addresses and Postcodes (Appendix 6)
- Print-out of Packets with IP Addresses (Appendix 7) **or** Packets with IP Addresses and Postcodes (Appendix 8)

## Introduction:

Although we have based this lesson on a physical address, there is no reason why the teacher couldn't replace the postcode for a mobile telephone number. The benefit of using a mobile telephone over a postcode is that it demonstrates how mobile telephone number is not at a fixed geographical location, like the IP address for a mobile digital device but what the postcode and mobile telephone number have in common is that they are both unique identifiers like the IP Address.

## How could I teach this in my classroom?

### New vocabulary:

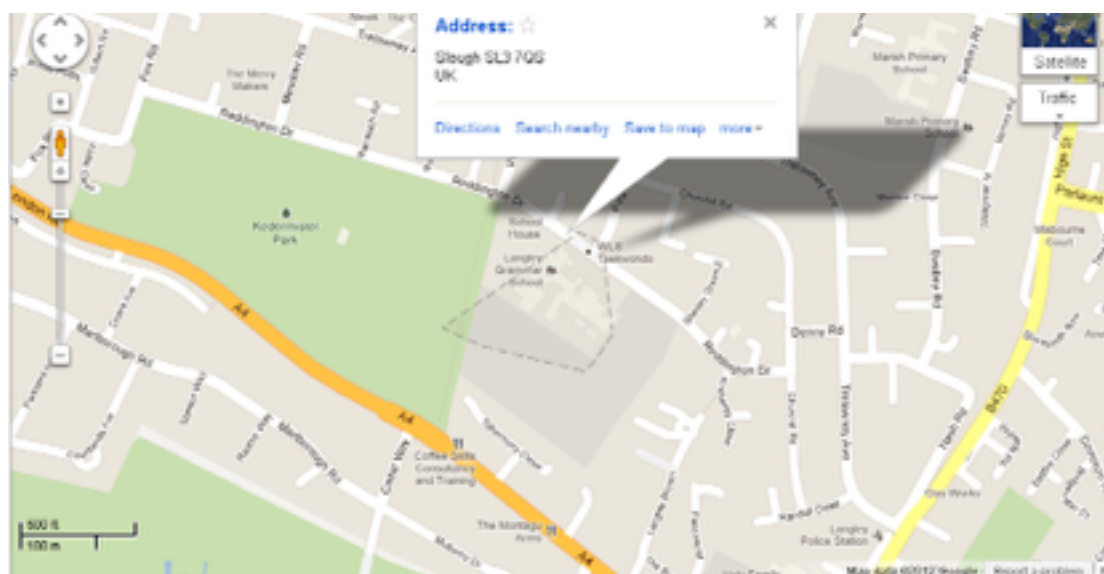
- Postcode
- Source
- Destination
- IP address
- IPv4

### Instructions:

Begin the lesson by asking the pupils how they think the UK postcode system works. Ask the pupils to share their postcode with the class and where the pupils share a postcode that matches another, ask the pupils how they know that the pupils do not live together i.e. the house number.

The teacher can then show the pupils a well-known mapping system. Search for the first part of a local postcode. For example, search SL1 to show the centre of Slough. Then repeat this process for the other local postcodes, for example SL post codes between 1 and 5 to show how the area changes on the map.

The teacher should choose to show their school postcode last of all. The first part of the postcode should display the road from a high level. Slowly drill down on the school by entering more of the postcode which provides a more specific area. Keep adding more of the postcode until eventually the school is located. See figure 6 below:





**Figure: 6 Google maps**

Now change the last section of the post code, for example SL3 7QS to SL3 7QR and again for SL3 7QZ etc. The pupils should notice that the area covered by the post code changes. Refer to figure 7 below:



**Figure: 7 Google maps with post codes**

Repeat the networks unplugged activity from the last lesson (lesson 4) but this time rather than writing a pupils' name on the source and destination boxes, give each of the pupils a postcode. Make sure you do not announce the destination, instead write it on each of the packets envelopes only. By completing this activity, it provides the perfect foundation for introducing DNS and routers at lower secondary school.

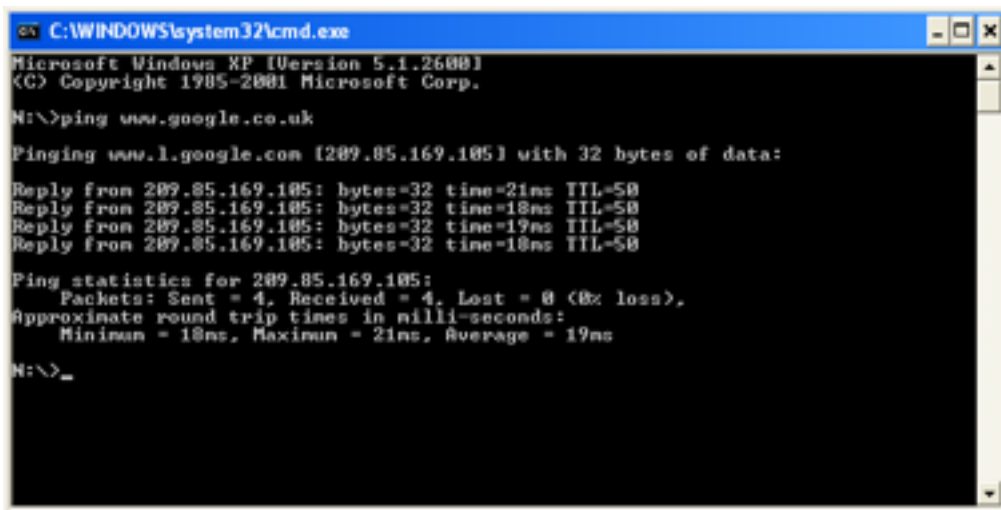
With experience, the class teacher will find that the pupils will pass the packets around the room randomly, especially if they all are both source and destinations i.e. there are multiple message with multiple associated packets. When the packets have been put together to recreate the file, ask the pupils what technique they used. They will say that they simply checked if the packet was for them. If it isn't then they pass the packet on to another child.

The pupils will probably say that after a few of the packets had reached their destination then they had a clue of where to send the other packet to. The teacher should explain to the pupils that the internet doesn't do this. Repeat the networks unplugged activity but this time send out multiple packets with a varying number of packets through the human network so that you have multiple sources and destinations.

Now, either open up the application called 'cmd.exe' on the teacher's computer which is located in the following location: C:\WINDOWS\system32\cmd.exe. Alternatively, if the command line

(CMD.exe) is blocked in your school, you can complete this activity online by opening a web browser and navigating to the following website: <http://network-tools.com/> .

In the DOS prompt window or on the website, type in the following 'ping www.google.co.uk'.



```
C:\WINDOWS\system32\cmd.exe
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

N:\>ping www.google.co.uk

Pinging www.l.google.com [209.85.169.105] with 32 bytes of data:

Reply from 209.85.169.105: bytes=32 time=21ms TTL=50
Reply from 209.85.169.105: bytes=32 time=18ms TTL=50
Reply from 209.85.169.105: bytes=32 time=19ms TTL=50
Reply from 209.85.169.105: bytes=32 time=10ms TTL=50

Ping statistics for 209.85.169.105:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 10ms, Maximum = 21ms, Average = 19ms

N:\>
```

**Figure 8: Command prompt**

Ask the pupils what they noticed happened? The class teacher should begin a discussion and focus it on the number of packets sent/received. If the pupils do not notice that the website URL has been turned into a series of numbers then point them at what comes after the 'ping statistics'. If they are still struggling then ping another website URL.

Explain to the pupils that this series of numbers is called an IP Address. IP stands for 'Internet Protocol.' Notice in figure 8 above how there are four groups of numbers e.g. 209.85.169.105. This is known as IPv4.

You are going to repeat the internet unplugged activity with the pupils. Depending upon how your pupils have grasped the link between a postcode and an IP address i.e., they are both unique identifiers, you can either give the pupils just the IP address or both the IP address and postcode. Again send out multiple packets to ensure that the pupils are only checking for their packet and if not their packet, then passing it on.

Again either open up the application called 'cmd.exe' on the teacher's computer which is located in the following location: C:\WINDOWS\system32\cmd.exe. Alternatively, you can again open a web browser and navigate to the following website: <http://network-tools.com/> .

In the DOS prompt window, type in the following 'ping www.google.co.uk' and then again 'ping www.google.co.in'.

Record the two IP Addresses on the white/chalk board. See table 3 below.

|              |                |
|--------------|----------------|
| Google.co.in | 209.85.169.103 |
| Google.co.fr | 209.85.169.147 |

**Table 3: Website IP Addresses**

Ask the pupils what they notice about the IP addresses? Prompt the pupils by asking them what they can conclude about the location of the two servers hosting the websites based on what they know about the post code system? From the experience in the DSH, the pupils tend to say that they are in the next street to one another.

Continue this learning by either reopening the application called 'cmd.exe' on the teacher's computer which is located in the following location: 'C:\WINDOWS\system32\cmd.exe'. Alternatively, open a web browser and navigate to the following website: <http://network-tools.com/>.

In the DOS prompt window, type in the following 'tracert www.google.co.uk' to trace or record the route from the source IP Address to the destination IP address as well as all the servers that it passes through. For example, see figure 9 below that shows the route from Langley Grammar School to google.co.uk.

```

C:\WINDOWS\system32\cmd.exe
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

C:\WINDOWS\system32>tracert www.google.co.uk

Tracing route to www.l.google.com [209.85.169.103]
over a maximum of 30 hops:
  0  5 ms  1 ms  1 ms  10.168.68.1
  1  5 ms  4 ms  4 ms  ip-87-85-32-1.npl.easynet.net [87.85.32.1]
  2  6 ms  7 ms  8 ms  217.284.111.26
  3  21 ms  20 ms  17 ms  te0-0-0.er101.blln.uk.easynet.net [87.86.72.19]
  4  14 ms  18 ms  36 ms  ip-89-200-130-7.ov.easynet.net [89.200.130.7]
  5  *      25 ms  13 ms  72.14.219.252
  6  19 ms  19 ms  19 ms  209.85.255.76
  7  15 ms  11 ms  11 ms  209.85.253.92
  8  22 ms  18 ms  16 ms  66.249.95.173
  9  22 ms  17 ms  19 ms  209.85.250.161
 10  25 ms  24 ms  35 ms  216.239.43.102
 11  27 ms  21 ms  25 ms  bru02n01-in-f103.1e100.net [209.85.169.103]

Trace complete.

C:\WINDOWS\system32>

```

**Figure 9: Command prompt Trace Route**

Open a web browser and navigate to the following website:

<http://www.geobytes.com/IpLocator.htm?GetLocation>

The pupils are to use the IP addresses from the DOS Prompt screen 'routert' in the above website to record the geographical route through the internet on a map of the world. A great hook for the pupils to do this activity is to watch the opening credits of the film Mission Impossible because it shows an elite team trying to trace and map a file's journey around the globe. See figure 10 below:



**Figure 10: Shows the source from Langley to the destination (google.co.uk) in California**

Image source: <http://www.geographyiq.com/world.htm>

Alternatively, you can use a graphical tracer tool online, such as, <http://www.yougetsignal.com/tools/visual-tracer/> which isn't quite as suitable for this lesson because it only traces the route from the website host server but is much more accessible for some pupils in upper primary school.

This provides the teacher with an excellent opportunity to discuss the implications (digital literacy) of pupils' actions on the internet. What if the pupils thought that they had mistakenly broken the law on a website with a French domain name i.e. name.org.fr but the server storing the website was based in China... what country have you broken the law in? Or even, what if they broke the law in one country but their packets of data travel all over the world... does that mean they have broken the law in all those countries?

## 6 The Binary behind IP Addresses

### **Summary:**

In this lesson the pupils will learn about the binary behind IP addresses, and relate this to IPv4. It is a transition lesson into lower secondary school learning outcomes. However, the national curriculum should be seen as the pupil's minimum entitlement so by covering some lower secondary subject knowledge, it enriches the pupils understanding of the subject.

### **National Curriculum PoS:**

- Key Stage 2
  - Bullet point 4
  - *"understand computer networks, including the internet; how they can provide multiple services, such as the World Wide Web, and the opportunities they offer for communication and collaboration"*
- Key Stage 3
  - Bullet point 4
  - *"understand simple Boolean logic [for example, AND, OR and NOT] and some of its uses in circuits and programming; understand how numbers can be represented in binary, and be able to carry out simple operations on binary numbers [for example, binary addition, and conversion between binary and decimal]"*

### **Progression Pathways:**

- Data & Data Representation: Purple
  - *"Know that digital computers use binary to represent data. Understands how bit patterns represent numbers and images."*
  - *"Know that computers transfer data in binary"*
- Networks & Communication: Purple
  - *"Understands data transmission between digital computers over networks, including the internet i.e. IP addresses and packet switching."*

### **Cross curriculum links:**

\* Maths

### **Age group:**

- Aged 10 upwards

### **Materials:**

- Binary cards from CS Unplugged

- Worksheet with some denary to binary activities
- Web browser with an internet connection
- Binary of IP Addresses (Appendix 10)

### Introduction:

**IP = Internet Protocol.** IP is an example of a protocol you should have heard of. All the computers, servers and routers that make up the Internet communicate using IP. IP addresses are made up of four numbers separated by three dots, e.g. 123.21.5.212 or 193.127.30.23

### How could I teach this in my classroom?

#### New vocabulary:

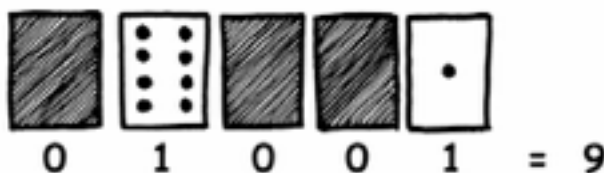
- Binary
- IP Address
- IPv4

#### Instructions:

The teacher should begin this lesson by recapping what IP address means.

The question of why IP addresses limited to three/four sets of 255 is sometimes asked by a pupil and it is the one part that they struggle to understand. From experience the best thing to do is break the explanation for the pupils down into the simplest building blocks i.e. binary.

You can introduce binary using a CS unplugged favourite CS Unplugged activity:



Activity source: [http://csunplugged.org/sites/default/files/activity\\_pdfs\\_full/unplugged-01-binary\\_numbers.pdf](http://csunplugged.org/sites/default/files/activity_pdfs_full/unplugged-01-binary_numbers.pdf)

| Number | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|--------|-----|----|----|----|---|---|---|---|
| 146    | 1   | 0  | 0  | 1  | 0 | 0 | 1 | 0 |
|        | 0   | 0  | 0  | 0  | 0 | 0 | 1 | 1 |
| 5      |     |    |    |    |   |   |   |   |
| 24     |     |    |    |    |   |   |   |   |
|        | 0   | 1  | 0  | 0  | 0 | 0 | 0 | 1 |
| 93     |     |    |    |    |   |   |   |   |
| 131    |     |    |    |    |   |   |   |   |
|        | 1   | 0  | 1  | 1  | 1 | 0 | 0 | 0 |
| 255    |     |    |    |    |   |   |   |   |

**Table 4: Denary to binary challenge**

If pupils haven't already done so, explain the task and give them time to complete the activity. See table 4 above.

The class teacher should conclude this first unplugged activity by asking the pupils what they notice about the number 255. The pupils will tell you that all the bits have the value of '1' with no '0'. See table 5 below:

| Number | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|--------|-----|----|----|----|---|---|---|---|
| 255    | 1   | 1  | 1  | 1  | 1 | 1 | 1 | 1 |
| 0      | 0   | 0  | 0  | 0  | 0 | 0 | 0 | 0 |

**Table 5: Value 255**

The row of 255 plus one complete row of zeros, and all the combinations in between, means that you have 256 combinations: 0 - 255.

All the computers, servers and routers that make up the Internet communicate using a protocol called IP (internet Protocol). IP addresses are made up of four numbers separated by three dots, e.g. 123.21.5.212 or 193.127.30.23. The four numbers have to be represented in 8 bits or a byte, so each can only be a number between 0 and 255. Therefore, each IP address is made of four bytes.

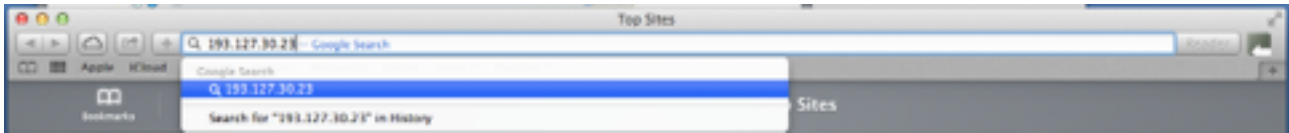
The computer sends the number in binary. We write the address as four separate numbers, as it is easier for people to understand. Then as the number of website grew and the popularity of the internet was realised, the domain name structure e.g. www.bbc.co.uk was masked over the top.

The class teacher should set the pupils a binary challenge to convert binary into denary (10 base) to find an IP Address which they then use in a web browser to open a website. See table 6 below:

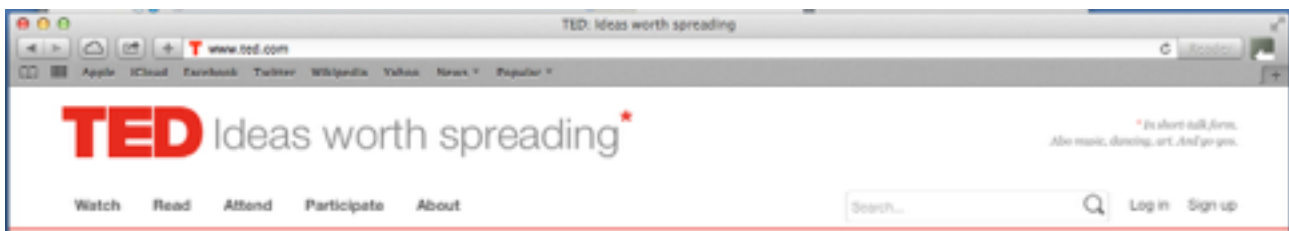
|          |          |          |          |
|----------|----------|----------|----------|
| 11000001 | 01111111 | 00011110 | 00010111 |
| 193.     | 127.     | 30.      | 23       |

**Table 6: IP Address in binary**

Once the conversion is completed, ask the pupils to open a web browser and enter the IP Address into the URL bar. Ask them what happens? See figure 11 and 12 below:



**Figure 11: Typing a URL into a web browser**



**Figure 12: The result "www.ted.com"**

Once the pupils have grasped the IP4 i.e. four numbers between 0 – 255 to make a unique address, it is interesting for the class teacher to ask the pupils at this point how many combinations they think you could have of IP addresses? Do they ever think we will run out?

This can make an interesting research challenge or a challenge for them to give to their Maths teacher on how many different unique number combinations they can make?

If the pupils think that it is possible for the number of unique combinations to run out one day, ask them to think how they would create even more unique combinations? Most pupils will tell you that they would increase the number of numbers in the IP address from four, to something like 5 or 6. At this point, the teacher can explain that they will be introduced to IP6 in secondary education.

Conclude this series of lessons covering the programme of study Key Stage 2 bullet point 4 by watching the following video and drawing comparisons between their understanding from the activities undertaken and the content in the video. See figure 13.





**Figure 13: How the web works**

Video source: <http://www.youtube.com/watch?v=90cfeFBid68>

## 7 Searching the Internet

### Summary:

This lesson will help the pupils to search the Internet more effectively by understanding the information presented to them from a search engine search results as well as being introduced to the role of a web crawler.

### National Curriculum PoS:

- Key Stage 2
  - Bullet point 5
  - *“use search technologies effectively, appreciate how results are selected and ranked, and be discerning in evaluating digital content”*

### Progression Pathways:

- Networks & Communication: Blue
  - *“Understands how to effectively use search engines, and knows how search results are selected, including that search engines use web crawlers”*

### Cross curricular:

- Literacy

### Age group:

- 7 years up

### Materials:

- Internet connection

### Introduction:

URL stands for **Uniform Resource Locator**. A URL is a structured string of text used by Web browsers and email clients to identify files on the network, including internet.

A program that searches for and identifies items in a database that correspond to keywords specified by the user, used especially for finding particular web pages on the Internet is called a **search engine**.

An internet bot known as a web spider or **web crawler** is used by search engines. They visit a list of URLs (called seeds). The web crawler updates the web content, including all the hyperlinks on the web page, and adds them to a list of web pages to visit (called crawler frontier), and these are then visited. This is also important for the **search engine page ranking** which is covered in later lessons.

### How could I teach this in my classroom?

#### New vocabulary:

- Search engine
- World wide web
- URL (Uniform Resource Locator)
- Web crawler

#### Instructions:

Begin the lesson by recapping what they learnt in the first lesson, reviewing what the following words mean, and see if they remember the difference between the internet and World Wide Web.

- Internet
- World Wide Web
- Server
- Client

Begin by tapping into what the pupils wrongly think the World Wide Web is, e.g. Google or Bing, i.e. a search engine. Rather than trying to address this misconception at the outset, alternatively relate internet searching to something that pupils should be used to, searching for a book at a library.

Ask the pupils what they consider when picking a book from the library? Show the pupils a book to help them. For example figure 14:



Figure 14: Secret Breakers by H. L. Dennis

The teacher usually gets the following answers:

- Title
- Blurb
- Author
- Size of the book
- Date published
- Design or illustration of the cover

The class teacher should encourage the pupils to do a search on one of the well-known search engines. Ask them to consider which one they will pick. Pupils will usually tell the class teacher that they will go for the top links without reading the blurb about the webpage which is surprising as most pupils consider the blurb on a book before using it.

The class teacher should ask the pupils to see if they can relate the criteria they check when selecting a book to the results from the search engine, see figure 15.

### Dictionary - Yahoo! Kids

Find pronunciations, definitions, spelling, and more in the free, online Yahoo! Kids Dictionary. Get help on your homework or just have fun learning.

[kids.yahoo.com/reference/dictionary/english](http://kids.yahoo.com/reference/dictionary/english) - 27k

**Figure 15: Search engine results**

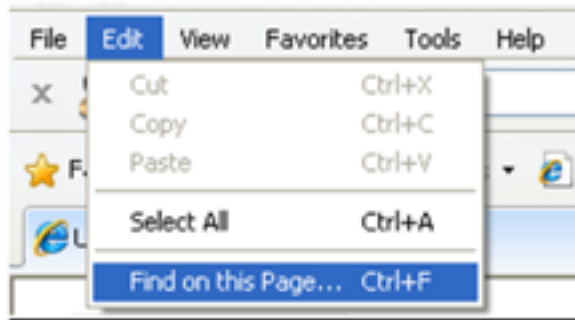
On completion of this activity, there is an opportunity to help the pupils relate the documents on the internet i.e. World Wide Web, to the books in the library. Therefore, rather than the search engine being the World Wide Web, they will recognize that it is a program for searching the digital artefacts stored on servers connected to the internet, which we call the World Wide Web.

If the pupils are still struggling with the understanding of the role of the search engine, the class teacher can take the pupils for a school trip to the local library where they can use the computer in the library to search for a particular item or book. Using the information it provides i.e. building, floor, category, isle, shelf number, the pupils can fetch the item they were looking for.

To extend the pupils and to encourage them to become more efficient with their searches and understand how a web crawler works, the pupils should be given a website link and a set of questions relating to the webpage. The questions relate to particular keywords on a webpage (this is great opportunity for some cross curriculum work). The questions could be to find particular keywords or the number of times a keyword appears on a webpage on the information contained in a sentence where that keyword is located.

The first few questions ask the pupils to search for the keywords manually, which take them quite some time i.e. the pupils have to scroll down the page looking for the answers. Then encourage

the pupils to look through the menu tabs in the web browser of choice to identify a relevant tool i.e. Edit > Find, see figure 16 below:



**Figure 16: Edit and find on a webpage**

Ask the pupils to search for the second five questions, but this time using the 'find' tool within the web browser. Also ask the pupils to find and list all the hyperlinks on the web page and their Uniform Resource Locator (URL).

It is important for the teacher during the plenary session to help pupils to evaluate the activities they have performed, including how they performed the role of the web crawler, as this will provide them with a useful foundation for how search results are selected and the order (rank) they appear in the results list in later lessons.

This lesson can also provide the class teacher with the opportunity to visit validity and trustworthiness of web pages, including consideration of fact, opinion and bias. For resources on how to teach this, we would recommend that you visit the Digital Schoolhouse website (<http://www.resources.digitalschoolhouse.org.uk/digital-literacy-a-esafety/105-dsh-online-epassport-primary> ).

## 8 How search engines select webpages

### **Summary:**

On completing these two activities in this lesson, it will provide pupils with both an understanding of how the pages are selected, including an introduction to Boolean logic. It will also show how to use this understanding to improve their use of search engines by using keyword search criteria and Boolean logic to narrow or broaden search results.

### **National Curriculum PoS:**

- Key Stage 2
  - Bullet point 5
  - *“use search technologies effectively, appreciate how results are selected and ranked, and be discerning in evaluating digital content”*

### **Progression Pathways:**

- Networks & Communication: Blue
  - *“Understands how to effectively use search engines, and knows how search results are selected, including that search engines use web crawlers”*
- Networks & Communication: Blue
  - *“Performs more complex searches for information e.g. using Boolean and relational operators”.*

### **Cross curriculum links:**

- All

### **Age group:**

- 9 years up

### **Materials:**

- Print-out of Search Engine (Appendix 11)
- A4 paper and pencils
- Large classroom
- Access to the internet

- Possibly PE hoops if you want to make the Venn diagrams more visual for the class

### Introduction:

**Boolean searches** allows a user to combine words and phrases using connective words (otherwise known as Boolean operators) such as AND, OR and NOT when asking questions of the data. The purpose of using these Boolean operators can be to limit (narrow), widen (broaden), or define your search.

**Venn diagrams** comprise of two or more overlapping circles which will be the case for our Internet searches. The interior of the overlapping circle represents the elements of the set, while the exterior parts of the circles represents elements that are not members of the set.

The use of **brackets** within the where clause of a query is similar to the use of brackets in a mathematical equation.

The computer is expected to identify the data that meets the first criteria before performing a second filter on only the records that met the first criteria. In Figure 17, the records must meet the criteria of 'Yes' for the field *Earring* and then either meet the criteria of *Glasses* or be *Female*. Refer to Figure 17 for example.



**Figure 17: Earring AND (Glasses OR Female)**

Without using the brackets in the query – this would produce a very different result. You would be asking the computer for the records that have both an *Earring* and *Glasses*, alternatively they could be *Female*. Refer to Figure 18 for example.



**Figure 18: Earring AND Glasses OR Female**

## How could I teach this in my classroom?

### New vocabulary:

- Keyword criteria
- Boolean search
- Clauses with brackets
- Venn diagram

### Instructions:

Begin this lesson by giving each child a card with a screen shot of a webpage on each card. If you are making your own, try to cover a range of cross curriculum subjects and topics. In particular, try and include websites where the same words can be used in different contexts i.e. 'war' could mean a BBC site covering a conflict somewhere in the world or the game 'world war 2' or the 'War-craft game'. This is particularly important when covering Boolean searches when narrowing down or broadening the search criteria. See figure 19 as an example.



Figure 19: Example webpage

The class teacher should explain that the classroom is the internet. The digital artefacts i.e. web-pages, are held by a server. Each pupil is a server storing multiple webpages i.e. each pupil has multiple cards. The pupils are given a list of possible keywords that the teacher might search for



during the activity, like the last lesson the pupils perform the role of a web crawler looking through their digital artefacts for the key words. To reinforce the role of the server, when the teachers does a search i.e. asks a question, the teacher details only the keyword criteria i.e. Vikings. The answer to whether or not the web page contains that key word and meets the criteria is going to be either “yes” or “no”. If the pupil is holding a card i.e. the server contains a webpage that meets the search criteria, then they, as the server, has something to ‘offer’ so they would stand up holding the card(s). If the pupil’s card doesn’t meet the criteria they should remain seated and not offer their card(s). The pupils will learn more about how the search engine uses the data from the web crawler to order the search results in the next lesson.

**If the class haven’t studied Boolean searches then you could introduce them by using the Databases Unplugged (<http://csunplugged.org/databases>) schemes of work available from CS Unplugged website.**

Boolean searches can be integrated into the activity by asking the pupils how we can make the process of doing multiple searches more efficient by removing the web pages that they don’t want from the search results. The pupils will come up with the suggestion to join the searches together.

This provides key questioning opportunities to identify connective words they use in literacy e.g. AND, OR and NOT, which could be used to join these searches. The pupils should have the opportunity to perform this learning using the server and webpage activity previously described.

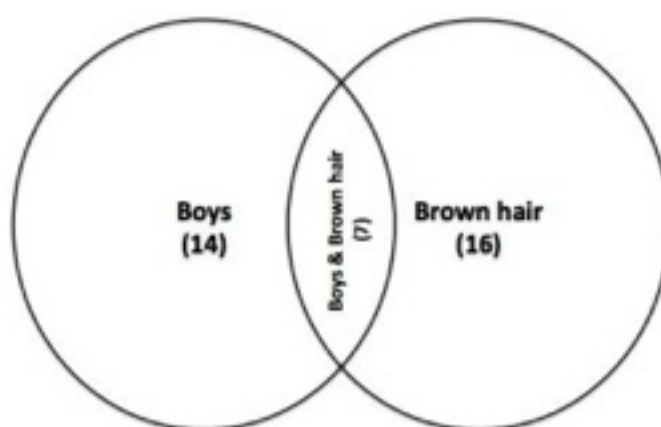
To conclude, the learning on Boolean searches asks the pupils to consider how the use of AND, OR and NOT affects the number of search results. If necessary, some of the kinaesthetic learning activity where the class teacher marks out a Venn diagram on the floor using PE hoops, masking tape or chalk so that pupils can step into the area, so that the pupils can count the number of “yes” and “no” answers for each question to reinforce their observations of:

- AND reduces (narrows) number of pupils
- OR increases (expands) the number of pupils

An engaging way to introduce the concept and assess the pupils’ understanding of Boolean logic is to search for the criteria “Boy AND Girl”! This generates some debate in the class when they realise that you cannot be both a boy and a girl!

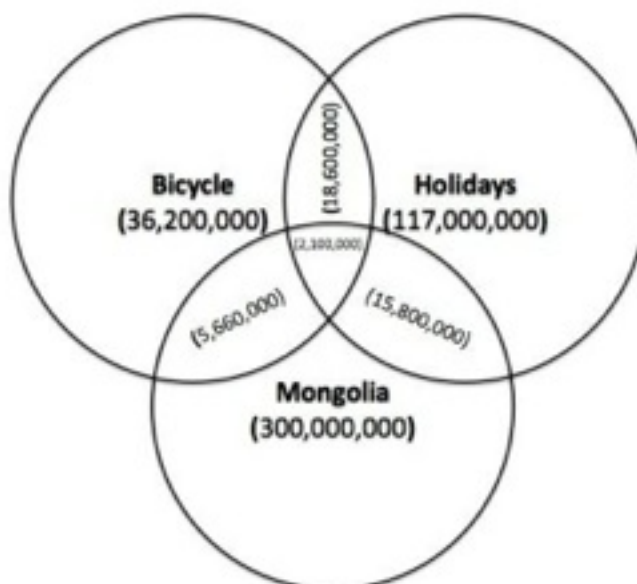
The pupils will then have more ownership of how to rephrase the question using a different connective i.e. OR, so that they are in fact standing in the right place.

This activity should be extended to cover the study of Venn Diagrams and use of a search engine. You can either base the development of the Venn diagrams on the results from the questions asked in the Human Search Engine activity where Boolean operators are used, see figure 19 below:



**Figure 19: Venn diagram for a human database**

Alternatively base it on the use of Boolean operators with a (recommended) maximum three search criteria using an internet search engine. The cross over between the circles represents the AND (narrowed criteria), with total of both the respective circles and the cross over representing the OR. See figure 20 below:



**Figure 20: Venn diagram for an internet search**

You can also help pupils to understand how Boolean logic can make these web searches more efficient. Pupils can model searches and results using a both a Venn diagram and a web browser to help them understand how the structure of the query affects (theoretically) the number of results. However, as a general rule of thumb most search engines will process operators from left to right.

To extend the more able or older pupils, the class teacher can combine Boolean operators (AND and OR) into the same query.

Furthermore, for the older or more able pupils, the class teacher can encourage them to relate the results to what they know about mathematics and use of brackets. However, it is important to talk through the syntax with them the first few times when acting out the role of the search engine.

## 9 How search engines rank the webpages into an order

### **Summary:**

This lesson will help pupils to understand how the search engine work i.e. how an algorithm ranks or orders the results for a given search.

This lesson described works for most pupils. However, if you don't think it is suitable for your pupils, then there is an excellent alternative activity available to teach the same learning outcomes: [http://www.code-it.co.uk/internet/howsearchworks\\_planning.pdf](http://www.code-it.co.uk/internet/howsearchworks_planning.pdf)

### **National Curriculum PoS:**

- Key Stage 2
  - Bullet point 5
  - *"use search technologies effectively, appreciate how results are selected and ranked, and be discerning in evaluating digital content"*

### **Progression Pathways:**

- Networks & Communication: Purple
  - *"Understands how search engines rank search results"*

### **Cross curriculum links:**

- PHSE

### **Age group:**

- 10 years up

### **Materials:**

- A4 paper and pencils
- Large classroom
- Access to the internet
- Print outs of the Doug Aberdeen webpages (Appendix 12)
- One dice per pupil

### **Introduction:**

A **search engine** is a computer programme that searches Web pages for the search terms entered by the user and provides a list of the pages in which they appear.

### **How could I teach this in my classroom?**

### **New vocabulary:**

- Algorithm

- Page rank

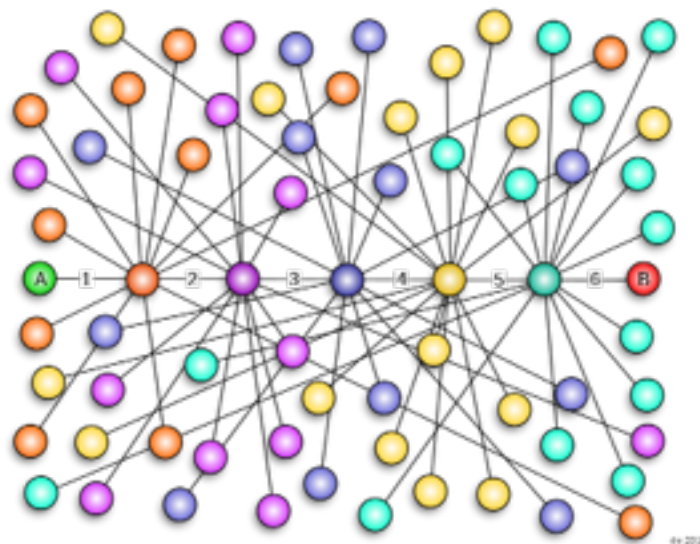
### **Instructions:**

Begin this lesson by consolidating the role of the search engine, that is, it is a computer program that provides a list of the web pages in which the search criteria entered by the user appears in.

Show the pupils a page of search results from a popular search engine. Pose the question to the children of how do they think the search engine orders these search results? Most pupils will say that they think it based on which web pages are most popular. This creates an excellent PSHE study opportunity to have a discussion around what is 'popularity'. Focus your key questioning around the fact that we are all part of, a number of small social groups of friends, each of which is relatively small.

Ask the pupils to think how their social groups differ from their friends e.g. through extra-curricular clubs. So in effect they are connected to people in other friendship groups they don't know via friends that they have in common. It is a nice idea to ask the children to identify friends that they have in common. The teacher should explain this is known as the Small-World theory or six degrees of separation.

There are some nice video clips available advertising a communications provider on the world wide web called "Three degrees of Kevin Bacon". Kevin Bacon is a famous Hollywood actor that scientists found that most other actors or actresses were connected to. See figure 21 below:



**Figure 21: Six degrees of separation**

[http://en.wikipedia.org/wiki/File:Six\\_degrees\\_of\\_separation.svg](http://en.wikipedia.org/wiki/File:Six_degrees_of_separation.svg)

It is helpful for future learning to remind the pupils that each social group is a network, and the interconnecting networks is how we describe the internet i.e. a network of networks.

The class teacher can develop this learning in a Digital Literacy direction by asking the pupils to list some of the websites they have heard about or use that to enable people to connect with one another and model their social groups e.g. Facebook. Ask the students to consider both the advantages and disadvantages of such websites. Ask whether they think that Kevin Bacon is the most popular actor. The answer will most likely be “no” but we are talking about him because he is very well connected with other people because the range of films and actors/actresses he has worked with.

Explain to the students that like in human networks, there is no central authority that governs which webpages should be connected to which, so therefore there is no one way of finding the web page you need. In the next activity, pupils will learn how search engines e.g. Google, use this idea of small-world theory when ranking the search results into an order.

Now that the pupils have a basic understanding of how the search engine selects results and understands what is meant by popularity, the Google Page activity created by Doug Aberdeen teaches children how the Google Page Ranking System actually works through a lovely kinaesthetic learning activity.



**Figure: 22 Douglas Aberdeen's Page Rank CAS Conference talk**

Although the entire video presentation (<https://www.youtube.com/watch?v=bNp4ZP5CDcA>) by Doug Aberdeen is well worth watching, the section within the presentation containing an explanation of how the Google search engine works is: From: **19** minutes and **49** seconds - To: **25** minutes and **02** seconds. For the lesson resources used in the presentation (<http://www.computingatschool.org.uk/index.php?id=aberdeen>)

The teacher pins up screen shots of web pages around the room. Each webpage has hyperlinks marked on it with a number. The children start at any webpage they like the look of or they can stand randomly at the webpages. The pupils roll the dice and move to the new web page that the number on the dice corresponds to. After a dozen or so rolls of the dice the pupils will notice that they will generally appear to move between the same web pages.

Ask the pupils why do they think this is? Encourage the pupils to focus on the work earlier in the lesson on what is 'popularity' and how the hyperlinks (connections) between the webpages make a webpage more popular. If the children struggle to make the connection between this learning then encourage them to examine the hyperlinks (connections) between the webpages; pupils should be considering which webpage hyperlinks appear the most on all the webpages and whether these were the same webpages that they ended up visiting most during the dice rolling activity earlier in the lesson.. The class teacher is trying to draw out of the pupils, through observation and discussion that the more webpages that link to a web page, the more popular the web page is going to be. As a result of more hyperlinks connecting to that webpage, the webpage will be presented higher up in the list of search results in the search engine which increases the chance of it being visited.

In summary, the algorithm that powers the computer program uses the data from the web crawler (that notes the hyperlink connections) to work out which webpages are the most popular and then it returns these at the top of the list of results that it delivers to you.

In the case of Doug Aberdeen's activity, see figure 23 below, the more stars a web page has the higher the number of hyperlinks that are directed to the web page. For example, web page A and web page B are both about vampires. If ten other web pages link to web page A and five other web pages link to Web page B, a search for 'vampires' will return web page A at the top of the list of results. Therefore, a webpage that has more pages linking to it will appear higher on the search results list; unless one of the hyperlinks directing to web page B had a much higher page rank value i.e. BBC or similar sized organisation, which in effect means that each hyperlink (connection) is weighted.

The pupils can understand this concept by likening it to the 'popularity' discussion earlier – by asking whether they think that if the most popular pupil in the school become your friend, would that raise your 'popularity' in school?



Figure 23: Example card from Doug Aberdeen's activity