



The evolution of computers in society

Addressing learning outcomes
and building key skills

Resources and strategies for the
**LEAVING CERTIFICATE COMPUTER
SCIENCE CLASSROOM**

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Overview

The Leaving Certificate Computer Science (LCCS) specification is constructed into 3 strands: Practices and principles, Core concepts and Computer science in practice. The learning outcomes are interwoven across the 3 strands. Many learning outcomes across all 3 strands can be achieved through a blended pedagogy of group activities with guided exploration and creative problem solving.

Suggestions on how to use this resource

This resource aims to primarily support the learning outcomes around Computers and society, and the evolution of computers in society, in **strand 1**, and also the core concept of Computer systems in **strand 2**.

The resources and strategies provided are intended mainly for the teacher to use in the classroom. They can be used in the context of an Applied learning task (ALT) or simply as classroom strategies to engage students in wider ethical and cultural questions. They are not prescriptive and the concepts do not have to be taught in the order they are presented. Teachers will discover many other ways of helping their students achieve the learning outcomes. Much of the learning around computers and society and the direction of technological development can be facilitated by teachers with classroom techniques, such as *Power of Persuasion*, *Think-Pair-Share-Snowball and Stimulate a Debate*, which are described within this resource. There are also design and development activities, plus ideas for other suitable activities. The resource itself, with guidance and differentiation from the teacher, can be used as a learning platform by students.

Material that is suitable for Higher Level only is indicated by an orange bar to the side.

The evolution of computers in society is outlined below. Each development in the evolution is used as a platform to study subsequent related developments. In this sense the learning outcomes can be achieved in an iterative and non-linear fashion. The [learning outcomes](#) can be viewed at curriculum online.

100 Years of Computing Developments



Early Computers
and Computing
Technology

1936
The Turing Machine

1942-1946
First Electronic Computers:
Colossus and ENIAC

1947
Solid State Transistors

1953
Invention of High Level
Programming Languages

1958
Integrated Circuits

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Mobile Phones and
Interconnected Computers

1977
First modern PC -
Apple II

1989
The World Wide Web

2000-2020
Cloud Computing
and the Smart Phone

Emerging trends in the 21st century



Encouraging successful groupwork

Here are some ideas on how to set up and encourage effective groups.

<p>Heterogenous members</p>	<p>Avoid friendship groups. At the start, students may object to being separated from their friends. Explain that the groups will change regularly. Groups could be generated randomly. Keep groups small to begin with.</p>
<p>Social skills need to be taught</p>	<p>Teachers must teach the skills needed for group work, such as listening skills, leadership skills (shared and rotated), conflict resolution skills, how to give feedback, how to encourage each other, etc. "Be Kind, specific, and helpful" (Berger)</p>
<p>Ensure everyone feels accountable for their own work and for the work of the group</p>	<p>Teachers can ensure that the group is accountable while at the same time making sure that there is individual accountability. For example by randomly selecting one student to explain the group's answer or giving out role cards so it is clear who is the designer, reporter, communicator, etc.</p>
<p>Create positive interdependence</p>	<p>The teacher structures work in such a way that students need each other in order to complete the task.</p> <p>This can be achieved:</p> <ul style="list-style-type: none"> ▶ when the teacher sets a shared task or goal, and explains that all the group members must be able explain how it was arrived at ▶ when resources are shared (one worksheet between each pair/small group) ▶ when the teacher requests one end product and there is a shared and named input from each member
<p>Both the task and relationships are important</p>	<p>Cooperative learning groups try to increase students' learning and maintain good working relationships. Students need to be reminded to observe how they are succeeding with both.</p>
<p>Make time for group reflection/evaluation</p>	<p>The students need time to discuss how well they are achieving their goals and how they are working together. Questions such as "What worked well in the group today?" and "How can you work better next time?" are useful.</p>

Adapted from Johnson, Johnson and Holubec, *Cooperation in the Classroom*.

Early Computers and Computing Technology

Humans have been trying to develop machines for a long time that can assist them with performing calculations and processing data. As populations grew and societies became more sophisticated over time, the need to process data increased dramatically.

The [crash course of early computers](#) traces these attempts from the abacus invented over 4000 years ago in Mesopotamia up to Hollerith's invention of punch cards in the late 19th century.

Two early 19th century pioneers of both the theory and mechanics of calculation were Charles Babbage and Ada Lovelace. He devised a general purpose machine which he called an [Analytical Engine](#). Lovelace realised the potential of such a machine beyond calculations and published the first algorithm intended for a computer.

The 19th century saw the invention of the telegraph and the telephone, Maxwell predicted radio waves to exist and published his laws of electromagnetism culminating in Marconi's transmission of radio waves across the Atlantic in 1901. By the 1920s automobiles had become affordable and the first modern electronic television was invented. Communication and travel were being revolutionised. The information revolution was about to begin.

Explore a [timeline of the history of computers and computing technology](#) from the 1930s to the present day.

Some questions to consider

There are some fundamental questions teachers and students should ask themselves as journey through the evolution of computers in society.

- ▶ Computational Thinking is humans solving problems, knowing that a computer is in the wings with processing power far in excess of human processing power. But the power of computers has increased exponentially.
 - 🔗 **Ask yourself:** *Does computational thinking change in nature as processing power changes?*
- ▶ Start-up companies no longer have to begin in offices. They can start in the homes of friends, computer clubs or famously people's garages. The Personal Computer and the digital revolution have empowered people to become entrepreneurs and programmers. People who have been disabled are being increasingly enabled by new empowering technologies.
 - 🔗 **Ask yourself:** *How has this empowerment become possible over the last century and will it last?*
 - 🔗 **Ask yourself:** *What is the role of adaptive technology in the lives of all human beings?*
- ▶ The digital revolution, particularly in the 21st century, has been called a disrupter of both business and of society. Major multinational hi-tech companies have established new models for calling a taxi, booking a hotel, staying in Bed and Breakfasts, booking a table in a restaurant and then distributing the food we don't eat.
 - 🔗 **Ask yourself:** *What are the positive and negative impacts of computing on culture and society?*
- ▶ Some innovations are a natural evolution from previous developments. However sometimes a new innovation startles the world, and is more revolution than evolution.
 - 🔗 **Ask yourself:** *How does the power of computing enable different solutions to difficult problems?*

1936

The Turing Machine

Learning Outcomes addressed in this section are listed below.

-
- 1.7 develop algorithms to implement key chosen solutions

 - 1.12 compare the positive and negative impacts of computing on culture and society

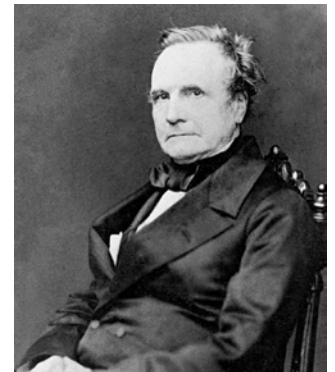
 - 1.13 identify important computing developments that have taken place in the last 100 years and consider emerging trends that could shape future computing technologies

 - 1.14 explain when and what machine learning and AI algorithms might be used in certain contexts

 - 1.18 recognise the diverse roles and careers that use computing technologies

 - 2.5 use pseudo code to outline the functionality of an algorithm

 - 2.8 apply basic search and sorting algorithms and describe the limitations and advantages of each algorithm
-



Charles Babbage

When other Learning Outcomes are addressed, for instance in classroom activities or through related online resources, the LO is numbered.

The birth of Computer Science and Machine Learning can be traced back to many ideas and early prototypes, such as Babbage's calculating machine in the early 19th century or Hollerith's punch card system from the end of the 19th century. There is however a strong case that Alan Turing's machine laid the foundations for the development of Computer Science and Machine Learning.

In 1936, Alan Turing invented a mathematical model of a universal machine, which later became known as a Turing Machine.

The  [operation of the machine](#) is a simple concept.

Despite its apparent simplicity, a Turing Machine can be constructed to solve any given computer algorithm.¹ It is in this sense, the first concept of a universal, all-purpose, computing machine. It provides computer science with a firm scientific foundation, since it offers a model of computation which can be tested against real world applications.

Classroom Activity

To demonstrate an algorithm on the Turing Machine with an unplugged version of the addition of two numbers.


A Turing Machine can, in theory, execute any algorithm a modern computer can execute. The Turing Machine, shown below, consists of an infinitely long paper tape comprising an infinite number of cells. A read/write head points to a particular cell at any given time. There are only 3 operations that can be performed on the tape:

1. Read the value
2. Write a new value (0,1, BLANK)
3. Move the read/write head to the next cell.

The # symbol in the diagram below will be interpreted in this case as ADD. The machine itself is oblivious to the symbol, as the algorithm is deciding that # in this case means addition. An example of the steps of an algorithm to perform $2 + 3$ are outlined below. The values, 2 and 3, are bookended by blanks. **We want to end our execution of the algorithm with five 1's in a row, bookended by BLANKS.**

Demonstrate the operation of the pseudocode below to students before assigning roles.

[How to explain the importance of the Turing Machine?](#) Visit [runestone academy](#)

 Use the classroom unplugged activity below to perform the addition of $1 + 2$ on a Turing Machine.

LO 1.3-1.8, 1.13
LO 2.5

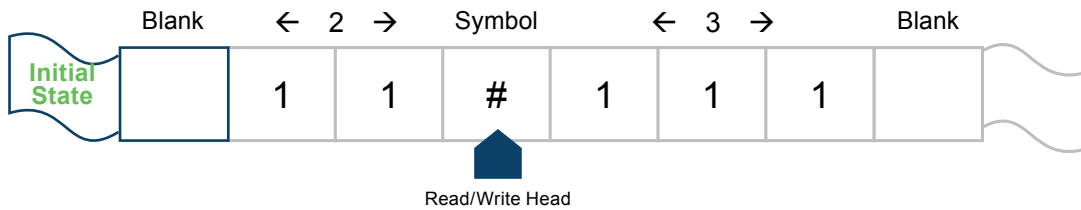
Learn how to assemble another unplugged algorithm.

[An unplugged punch card lesson, with video demonstration.](#) From the [teachinglondoncomputing website](#).

LO 1.7
LO 2.8

¹ Sipser (2006) *Introduction to the Theory of Computation* Thomson Course Technology, USA.

1. Draw a representation of the infinite tape on a whiteboard (or any display board). The initial state is shown below.



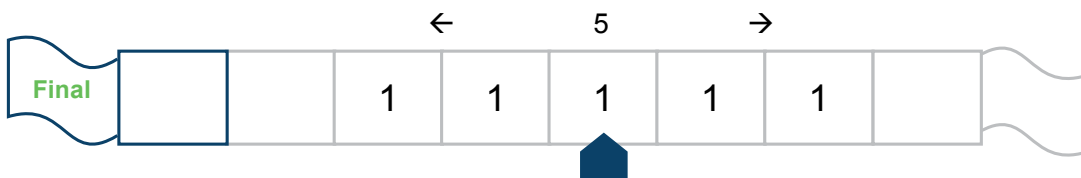
2. Move LEFT; Read the value;
REPEAT until the value == BLANK {
 Write 0;
 Move LEFT;
 Read the value;
}



3. Move RIGHT; Write a BLANK;
Move RIGHT; Read the value;



4. REPEAT until the value == 1 {
 Write 1;
 Move RIGHT;
 Read the value;
}



The classroom activity requires 3 students to execute individual operations at the whiteboard. Another group, which could be the rest of the class, ensure the steps of the algorithm are carried out correctly. They are the control unit.

The 3 people with specific individual roles are:

The READER

The role is to read the value in the cell where the read/write head is pointing. The Reader must read out the value from the whiteboard as instructed, even if the algorithm is operating incorrectly.

The WRITER

The role is to write a value into the cell where the read/write head is pointing. The state of the Turing machine will be updated by the writer on the whiteboard.

The read/write HEAD

The role is to re-draw the position of the read/write head on the whiteboard, according to the instructions issued by the control unit. The head can be represented by the shape shown in the example, or any similar symbol that is appropriate.

The challenge is to carry out the addition of any two natural numbers. For example, 2+1 or 2+5 or 3+3.

A further challenge, at an appropriate stage of the course, could be to program the algorithm in Python or JS with a suitable UI, to carry the out the addition of any two user-defined natural numbers.

⚙️ Turing Machine Addition Activity

The activity addresses a [range of LOs](#).

In particular:

- ▶ Computational Thinking LOs in Strand 1 (**LO 1.1-1.10**)
- ▶ Computers and Society LOs in Strand 2 (**LO 1.13-1.14**)
- ▶ Algorithm LOs in Strand 2 (**LO 2.5-2.7**)

Watch a [video showing basic arithmetic](#) on the Turing machine. The algorithm for addition is in the first minute.

Explain how it is different to the algorithm in the classroom activity.



Brain Buster

Alan Turing was also fascinated by such a machine's ability to think

"The original question, "Can machines think?", I believe too meaningless to deserve discussion. Nevertheless I believe that at the end of the century the use of words and general educated opinion will have altered so much that one will be able to speak of machines thinking without expecting to be contradicted."

Computing Machinery and Intelligence. Turing (1950)

After reading the quote in the Brain Buster, was Alan Turing's belief correct?

Facilitate a walking debate or TPSS activity.

LO 1.13, 1.14

What is Artificial Intelligence (AI)?

Humans have been thinking about AI for many centuries. The term Artificial Intelligence was only coined in 1955 by John McCarthy as: "the science and engineering of making intelligent machines." The following year, 1956, it was founded as an area of academic research during a workshop in Dartmouth College.² The goal of AI is to teach computers to do things that humans do, only better. One of those key things is learning. Machine Learning is therefore in some ways a subset of AI, but it has grown so rapidly in the early 21st century that some people argue it has outgrown AI.

Machine Learning (ML) Algorithms

There are 2 broad categories of ML: supervised and unsupervised. For example, let's consider items needing to be sorted into waste and recyclables. Supervised learning would require humans to examine the categorisation performed by the algorithm and tell the algorithm, using labels, which items have been incorrectly sorted. An unsupervised algorithm will identify patterns in both the input and output, perhaps correlating existing categorisation, with statistical analysis, to sort the items. Both systems improve, but in different ways.

Alan Turing was also famous for the [Turing test](#).

Can you tell the AI from the human in these [short breakthrough phone calls](#) released at a Google IO event in 2018?

What do you think the T in the abbreviation [CAPTCHA](#) stands for?

² https://en.wikipedia.org/wiki/History_of_artificial_intelligence

The following links give 3 examples of each of the 2 main categories of Machine Learning.

[Supervised Learning](#) uses training (input) data and if certain outputs are incorrect, the algorithm is notified not to output this in future. It relies on good data and some feedback.

[Unsupervised Learning](#) allows the algorithm to spot patterns and decide itself which outputs are most useful. It does not rely on feedback.

Within these categories there are [five popular schools of machine learning algorithms](#)³:

1. SYMBOLISTS

This is closely related to mathematical thinking. They believe all intelligence can be reduced to manipulating symbols. By combining pre-existing knowledge with new data, and incorporating it into the machine, new learning will take place.

2. CONNECTIONISTS

This is related to neuroscience. They believe that strengthening connections between neurons/logic gates will improve the machine's learning and similarly eliminating connections that cause errors in outputs. By looking at the output and comparing it to the correct output, the connections that require modification can be identified. This is known as backpropagation.

3. EVOLUTIONARIES

This is related to evolution by natural selection. The concept of genetic programming is very strong where the best programs are merged together evolving into better programs. The less successful programs are disposed of creating a constantly evolving structure capable of new learning.

4. BAYESIANS

This is related to a theorem in probability called Bayes Theorem. Bayesians, using probability, combine new evidence with existing beliefs to infer new ideas. Learning itself, they believe, is uncertain knowledge.

5. ANALOGISERS

By comparing two things which have similarities, perhaps other characteristics are similar. For example if two patients share symptoms, perhaps they have the same underlying illness. By remembering the correct situations, and combining those things that are similar, new learning can be achieved.

Learning Opportunity: The types and uses of Machine Learning

▶ Watch an in-depth video on the [categories and uses of Machine Learning](#).

Now examine and discuss when machine learning and AI algorithms might be used in certain contexts.

LO 1.14

3 Domingos (2015) *The Master Algorithm* Penguin Books

What is Driving the AI and Machine Learning Expansion?

AI and Machine Learning systems have been around for decades yet the self-driving car, for example, has only become a possibility in the second decade of the 21st century. Why? [Why this seemingly sudden explosion.](#)

- ▶ Have humans become better at designing algorithms?
- ▶ Is a computer's processing of the real world now approximating a human's?
- ▶ Are there more quantities of useful data available to humans and computers?
- ▶ Is the rapid expansion going to continue? What are the emerging trends?

Predicting future trends and technologies is extremely difficult.



In 1973, the invention of wifi and radio technology made mobile phones possible.

How difficult would it have been back then, to predict the future technologies available 40 years later in 2013? In 40 years time how will technology shape our world? What trends will underpin that technology.

"The bits explosion is not over. We are in the middle of it. But we don't know whether it will be destructive or enlightening. The time for deciding who will control the explosion may soon be past. Bits are still a new phenomenon – a new natural resource whose regulatory structures and corporate ownership are still up for grabs. The legal and economic decisions being made today, not just about bits but about everything that depends on bits, will determine how our descendants will lead their lives. The way the bits illuminate or distort the world will shape the future of humanity." ⁴

Data, Algorithms and Processing Power

Take the [Crash Course](#) on AI and Machine Learning.

Facilitate a discussion around the rapid expansion of AI technologies, and the reasons behind the expansion.

LO 1.13, 1.14

One trend being widely predicted is the area of quantum computing.

[Watch a short video on Quantum Computing.](#)

[Classical versus Quantum Computers... a 10 minute explanation.](#)

LO 1.13, 1.14

⁴ Abelson, Ledeen, Lewis (2008) Blown to Bits Addison-Wesley.

1942–1946

First Electronic Computers: *Colossus and ENIAC*

Learning Outcomes addressed in this section are listed below.

-
- 1.11 discuss the complex relationship between computing technologies and society including issues of ethics

 - 1.12 compare the positive and negative impacts of computing on culture and society

 - 1.13 identify important computing developments that have taken place in the last 100 years and consider emerging trends that could shape future computing technologies

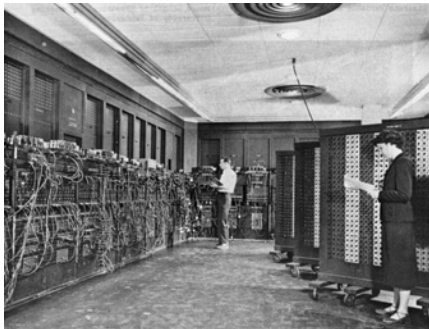
 - 1.18 recognise the diverse roles and careers that use computing technologies

 - 2.11 describe the different components within a computer and the function of those components

When other Learning Outcomes are addressed, for instance in classroom activities or through related online resources, the LO is numbered.

What constitutes a computer? Charles Babbage designed a mechanical computing machine called the [Difference Engine](#), in 1822. Babbage's later concept for an Analytical Engine is considered the first general mechanical computer comprising a basic processing and storage of data. In addition Ada Lovelace published an algorithm for the machine and showed it could be programmed by punch cards. In the late 1930s [Konrad Zuse](#) designed the Z1, an electro-mechanical programmable computer. The Harvard Mark 1 was a more sophisticated version which was first programmed by John von Neumann at the end of World War II. However the Colossus was the first fully programmable electric computer. Invented and designed by Tommy Flowers and Alan Turing, it made a major contribution to ending WWII when it helped to crack the codes of Nazi encryption machines. Simultaneously in the USA, Eckert and Mauchly built the ENIAC (Electronic Numerical Integrator and Computer), which is often considered to be the first example of a general purpose digital computer.

The components of the first programmable computers



The ENIAC

The first electronic computers, Colossus and ENIAC, weighed tons, occupied large rooms, and before the invention of semiconducting transistors, switching was executed by vacuum tubes (thermionic valves). Military advances during WWII spurred innovation and fast-tracked the invention of the ENIAC. The Colossus was re-built in Bletchley Park, the top secret British site of WWII decryption. It went live on 6th June 1996.

▶ [Watch this Computerphile tour](#) of the operation of the machine.

The Babbage analytical machine, as explained in the video on the evolution of computing devices, had 4 revolutionary features: Input, Storage, Processing and Output components. Sequential flow control and looping operations were fundamental to his concept. Today, the [inside of modern computers is not that different](#).

▶ [Watch a short video on the evolution of computing devices.](#)

- ▶ What 4 features of the Babbage machine made it revolutionary?
- ▶ Name components that act as switches?
- ▶ What was the first microprocessor used for?

Explore the [Human Brain Project](#) website to see the latest advances in how our brains could be simulated.

LO 1.13

LO 2.11

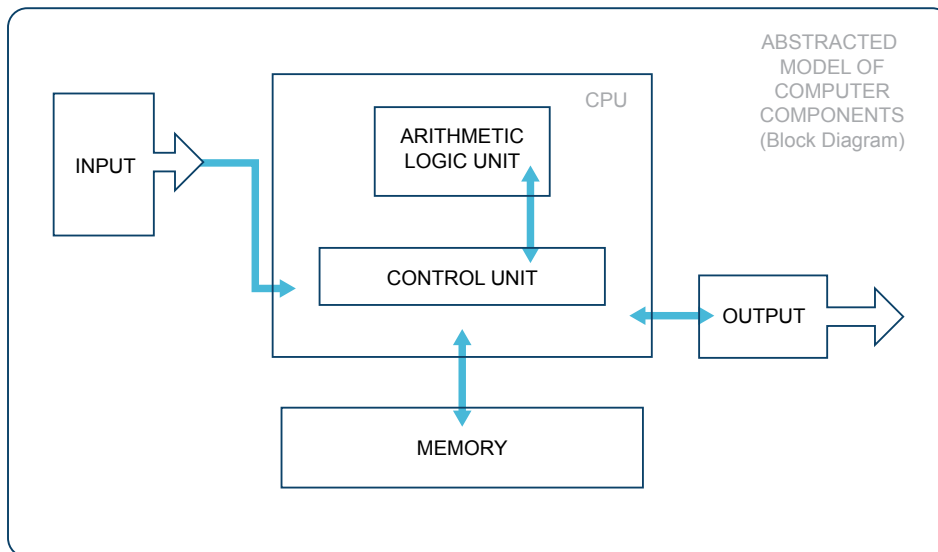
▶ [From Enigma to ENIAC and John von Neumann's contribution to the modern programmable computer. The first use of computers in 1952 to predict US election results.](#)

The history and development of the ENIAC (0-7:44) and the path forward after WWII (7:44-12:47)

LO 1.11

LO 2.11

The Arithmetic Logic Unit (ALU), where instructions are actually carried out, is probably the only functional unit that is extra to the original concept, as shown in the schematic block diagram below.



The complex relationship between society and computing technology is demonstrated clearly through the invention of the Colossus and ENIAC. The Colossus had a real impact on the war, shortening it by 2 or 3 years.⁵ Processing data, encrypting and deciphering codes and crunching numbers became key factors in deciding the outcome of WWII.

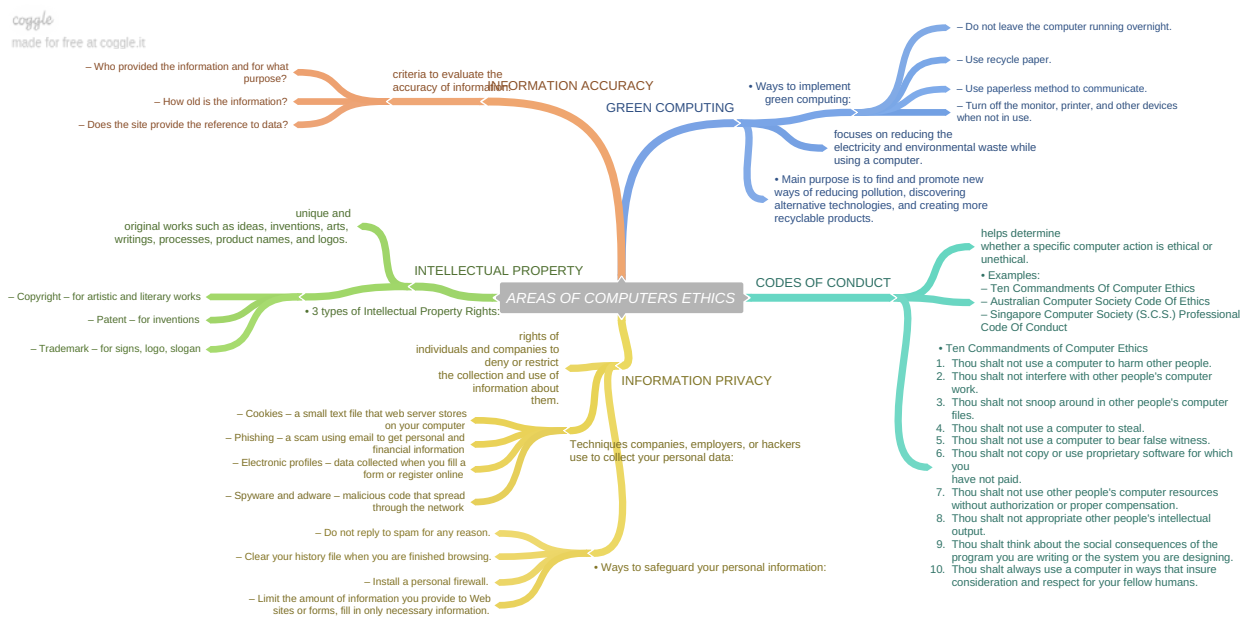
Would the first electronic computers have evolved so rapidly, almost independently of each other, without the impetus of a world at war? Many military innovations become mainstream technologies. For example, the US Defence Advanced Research Projects Agency (DARPA) developed the Arpanet⁶ in the late 1960s. It connected 4 nodes in the USA, developed IP addresses and invented TCP and UDP networking protocols. In the 1980s it evolved into the Internet.

5 BBC homepage and news <http://www.bbc.com/news/technology-18419691>

6 Wang (2016) *From Computing to Computational Thinking* CRC Press (p 97-98).

However ethics and computing technology spreads into our everyday life. The [coggle mindmap](#) below delves into all the areas where people, society and business must think not just about “Can I do this?” but “Should I do this?”.

Lots of websites suitable for LCCS that explore computers and society can be filtered on www.compsci.ie.



The following is a worked example suggesting how to *Stimulate a Debate* on an ethical question. It creates a classroom context in which to explore the complex relationship between military innovations, especially during wartime, influencing computing technology in society.



Stimulate a Debate on the positive and negative impact of military innovations on both society and technological developments.

The model for this activity is explained in [A Summary of Teaching & Facilitation Methodologies](#).

1. Watch a Stimulus Video or read a stimulus piece.

▶ [A video of 5 DARPA innovations that have become everyday technologies](#)

2. Prompt questions to provoke class discussion and elicit initial viewpoints.

- ▶ Can you name some military inventions that have shaped our world, both positively or negatively? ([from nuclear technology to drones to GPS!](#))
- ▶ How would the Internet be different if a commercial company invented it instead of the US Arpanet?
- ▶ Without the invention of the nuclear bomb, would we have nuclear power stations? Would we have less or more understanding of our universe and the sub-atomic world?
- ▶ Do you think the first electronic computers (Colossus and ENIAC) would have developed in different ways and at a different pace?

3. Divide into research groups to explore the topic from key standpoints.

The positive and negative impacts of military innovations on society and on technology.

Themes for different groups:

1. Military innovations, including wartime inventions, have an overall positive impact on society and on technology.
2. Military innovations, including wartime inventions, have an overall negative impact on society and on technology.
3. Societies advance rapidly, from a technological point of view, when there is a strong military and especially during wartime.
4. Societies advance slowly or not at all, from a technological point of view, when there is a weak military or no military at all.

4. Choose a teaching and facilitation methodology.

- a. Students first research each topic in research groups of 3.
- b. Use a Jigsaw technique to create groups of 3 comprising one student from 3 different themes. Each person discusses their research within their new group.
- c. Reassemble into original groups.
Each group has up to 5 minutes in the *Hot Seat* OR
A *Power of Persuasion* technique is used to group students into their preferred category and try to convince other students over to their viewpoint. OR
Think-Pair-Share-Snowball a general class discussion.

LO 1.11

Students should be able to discuss the complex relationship between computing technologies and society including issues of ethics.

1947

Solid State Transistors

Learning Outcomes addressed in this section are listed below.

1.16 compare two different user interfaces and identify different design decisions that shape the user experience

2.3 implement modular design to develop hardware or software modules that perform a specific function

2.11 describe the different components within a computer and the function of those components

2.12 describe the different types of logic gates **and explain how they can be arranged into larger units to perform more complex tasks**

2.13 describe the rationale for using the binary number system in digital computing and how to convert between binary, hexadecimal and decimal

2.14 describe the difference between digital and analogue input

When other Learning Outcomes are addressed, for instance in classroom activities or through related online resources, the LO is numbered.

The digital revolution, it can be argued, began in 1947 with the invention of the solid state transistor. John Bardeen, Walter Brattain, and William Shockley, working for Bell Labs in the USA, developed the revolutionary semiconductor device which can act as a switch, turning tiny electric currents on or off, and also as an amplifier of electric current, boosting electric currents.

The operation and function of modern solid state transistors (using n-type and p-type semiconductors) are explained in this [series of videos on basic electronic components](#).

Why Binary?

When transistors work as switches they can act as a computer's memory. When a switch is turned ON it is effectively storing the number 1 (high voltage). When a switch is turned OFF it is effectively storing the number 0 (low voltage). Transistors therefore operate in 2 distinct states and since there are only 2 digits it is called a binary system.

BInary digi**TS** are better known by their shortened name of **BITS**.

▶ 8 bits makes up 1 byte

8 bits can represent 256 (2^8) numbers and hence 256 characters on your keyboard. The old system for representing text and numbers was ASCII but the Unicode system is now the most widely used. Check out the [Universal Transformation Format \(UTF\) codes for emojis](#).

▶ 1000 bytes is about 1 KiloByte

1 KB (kB also used) is exactly 1024 bytes. This is 2^{10} bytes. The base of 2 represents the fact that a bit is either ON or OFF. 1 KB is a couple of short paragraphs of text.

▶ 1000KB is about 1 MegaByte

1 MB is 1024KB or 1,048,576 bytes. This is 2^{20} bytes. MP3 audio is roughly 1MB of sound per minute.

▶ 1000MB is about 1 GigaByte

1 GB is 2^{30} bytes or approximately 1 billion bytes. PC RAM is measured blocks of GB

▶ 1000 GB is about 1 TeraByte.

1 TB is a million million bytes or to be exact 2^{40} bytes. Terabyte hard drives and the growth of cloud storage have made this unit of measurement part of common, everyday language.

[Learn about basic electronic components \(resistors, diodes, transistors, &c\) and an electronics timeline.](#)

From
explainthatstuff.com.

LO 2.14

[Representing data using Braille Binary, Decimal and Hexadecimal.](#)

From the CS Field Guide
(Tim Bell)

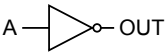
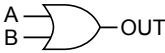
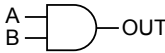
Check out this interactive [Stanford University site on measuring memory](#).

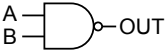
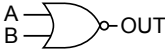
What do you think of its User Interface? Can you locate a better one? Why is it a better UI?

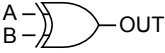
LO 1.16

LO 2.13

Logic Gates are the building blocks of computer systems. They are made up chiefly of transistors and enable computer systems to make decisions using [Boolean Algebra](#). The functionality of 6 logic gates is described below (NOT, OR, AND, NAND, NOR and XOR.)

Logic Gate	NOT	OR	AND																																												
Symbol																																															
Functionality (Truth Table)	<table border="1"> <thead> <tr> <th colspan="2">OUTPUT</th> </tr> <tr> <th>A</th> <th>not A</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>1</td> </tr> <tr> <td>1</td> <td>0</td> </tr> </tbody> </table>	OUTPUT		A	not A	0	1	1	0	<table border="1"> <thead> <tr> <th colspan="2">INPUTS</th> <th>OUTPUT</th> </tr> <tr> <th>A</th> <th>B</th> <th>A or B</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>0</td> <td>1</td> <td>1</td> </tr> <tr> <td>1</td> <td>0</td> <td>1</td> </tr> <tr> <td>1</td> <td>1</td> <td>1</td> </tr> </tbody> </table>	INPUTS		OUTPUT	A	B	A or B	0	0	0	0	1	1	1	0	1	1	1	1	<table border="1"> <thead> <tr> <th colspan="2">INPUTS</th> <th>OUTPUT</th> </tr> <tr> <th>A</th> <th>B</th> <th>A and B</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>0</td> <td>1</td> <td>0</td> </tr> <tr> <td>1</td> <td>0</td> <td>0</td> </tr> <tr> <td>1</td> <td>1</td> <td>1</td> </tr> </tbody> </table>	INPUTS		OUTPUT	A	B	A and B	0	0	0	0	1	0	1	0	0	1	1	1
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Logic Gate	NAND (not AND)	NOR (not OR)																																				
Symbol																																						
Truth Table	<table border="1"> <thead> <tr> <th colspan="2">INPUTS</th> <th>OUTPUT</th> </tr> <tr> <th>A</th> <th>B</th> <th>not (A and B)</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>1</td> </tr> <tr> <td>0</td> <td>1</td> <td>1</td> </tr> <tr> <td>1</td> <td>0</td> <td>1</td> </tr> <tr> <td>1</td> <td>1</td> <td>0</td> </tr> </tbody> </table>	INPUTS		OUTPUT	A	B	not (A and B)	0	0	1	0	1	1	1	0	1	1	1	0	<table border="1"> <thead> <tr> <th colspan="2">INPUTS</th> <th>OUTPUT</th> </tr> <tr> <th>A</th> <th>B</th> <th>not (A or B)</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>1</td> </tr> <tr> <td>0</td> <td>1</td> <td>0</td> </tr> <tr> <td>1</td> <td>0</td> <td>0</td> </tr> <tr> <td>1</td> <td>1</td> <td>0</td> </tr> </tbody> </table>	INPUTS		OUTPUT	A	B	not (A or B)	0	0	1	0	1	0	1	0	0	1	1	0
INPUTS		OUTPUT																																				
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Logic Gate	XOR (exclusive OR)																		
Symbol																			
Truth Table	<table border="1"> <thead> <tr> <th colspan="2">INPUTS</th> <th>OUTPUT</th> </tr> <tr> <th>A</th> <th>B</th> <th>A ⊕ B</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>0</td> <td>1</td> <td>1</td> </tr> <tr> <td>1</td> <td>0</td> <td>1</td> </tr> <tr> <td>1</td> <td>1</td> <td>0</td> </tr> </tbody> </table>	INPUTS		OUTPUT	A	B	A ⊕ B	0	0	0	0	1	1	1	0	1	1	1	0
INPUTS		OUTPUT																	
A	B	A ⊕ B																	
0	0	0																	
0	1	1																	
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From simple logic gates described below, the components of all computers can be constructed, such as flip-flops and memory components all the way up to ALUs and registers. In fact Arithmetic Logic Units (ALUs) comprise a vital part of the Central Processing Unit (CPU) of a computer. Logical and mathematical operations are performed here. The inputs to the ALU are controlled within the CPU by the control unit.

Analog v Digital is both very simple to understand at an abstract level and extremely complicated at the micro and quantum level. Explore the differences between analog and digital with this 5 minute [Techquickie video](#). Microprocessors such as the Arduino and Microbit enable both digital and analog processing. The revolution in semiconductors, which began in 1947 with the invention at Bell Labs of the solid state transistor, was in many ways the birth of the digital era: of 1's and 0's. Before that, our world was driven by analog technology. Now we live in both an analog and digital world.

Take the Crash Course [Video on Logic Gates](#).

From the Crash Course Series on YouTube (Carri Anne Philbin)

Watch how to [build logic gates and full adders using dominoes](#), plus an [explanation of binary arithmetic](#).

LO 2.3

[Interact with Logic Gates to explore how they work.](#)

The NAND gate can be made up from the output of an AND gate fed into the input of a NOT gate. Use the simulator above to demonstrate its operation.

Use this or a similar [interactive simulator to build a half-adder for the class activity](#).

An [animated and comprehensive look](#) at how computers add numbers.

LO 2.12

Watch the [NCCA video on battery testing using a microbit](#), then [implement in class to explore Digital and Analog signals](#).

Visit [ncca.ie](#) (computer science) or [compsci.ie](#) to view similar videos.

LO 2.14
LO 3.11-3.13

🔧 Classroom Activity

Design your own half-adder in some language you have learned, for example Python or Scratch.

What is a half-adder? The basic building blocks of an ALU are simple logic gates and one of the most fundamental elements of an ALU is the half-adder. The half adder takes two inputs in the form of bits, and outputs the sum and the carry-over. The addition and the Truth Table are shown below.

Addition of 2 bits
$A + B = CS$
$0 + 0 = 00$
$0 + 1 = 01$
$1 + 0 = 01$
$1 + 1 = 10$

INPUTS		OUTPUT	
A	B	Sum (S)	Carry (C)
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

The activity requires a minimum group of 3.

COMPONENT BUILDER

The role is to write functions in a programming language for the basic logic gates: AND, OR, XOR, NAND and NOR gates. The function should take 2 inputs (A,B) and output the result from the gate. The half-adder program will use these logic gate functions to simulate a half-adder.

HALF-ADDER DESIGNER

The role is to research half adder designs on the internet. With one of these designs, design an abstract model and algorithm to implement a half-adder design in your chosen programming language. The logic gate functions will be used within the overall model.

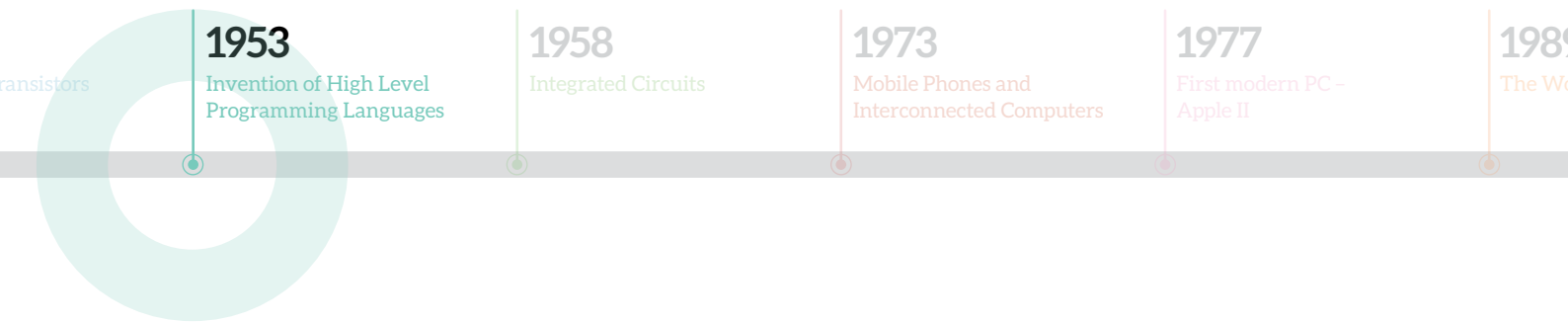
TESTER AND EVALUATOR

The responsibility is to ensure the half-adder outputs the correct values for all possible inputs. So, a program to perform such a test is to be designed. For example, a nested loop which generates every permutation of A and B in the Truth Table, which then feeds into the half-adder program. The program should also be tested for correct functionality and evaluated for efficiency and its Computational Thinking level. (See the [html NCCA resource for evaluating CT criteria](#) in block-based code.)

🔧 Half-Adder Activity

The activity addresses a [vast number of LOs](#). In particular:

- ▶ Designing and Developing LOs in Strand 1 (LO 1.19-1.23)
- ▶ Abstraction LOs in Strand 2 (LO 2.1-2.4)
- ▶ ALT3 Modelling and Simulation LOs in Strand 3 (LO 3.8-3.9)



1953

Invention of High Level Programming Languages

Learning Outcomes addressed in this section are listed below.

-
- 1.11 discuss the complex relationship between computing technologies and society including issues of ethics

 - 1.12 compare the positive and negative impacts of computing on culture and society

 - 1.13 identify important computing developments that have taken place in the last 100 years and consider emerging trends that could shape future computing technologies

 - 1.18 recognise the diverse roles and careers that use computing technologies

 - 1.22 read, write, test, and modify computer programs

 - 1.23 reflect and communicate on the design and development process

 - 2.4 illustrate examples of abstract models

 - 2.5 use pseudo code to outline the functionality of an algorithm

 - 2.6 construct algorithms using appropriate sequences, selections / conditionals, loops and operators to solve a range of problems, to fulfil a specific requirement

 - 2.7 implement algorithms using a programming language to solve a range of problems

 - 2.17 use ASCII and Unicode character sets to encode/decode a message and consider the importance of having such standards
-

When other Learning Outcomes are addressed, for instance in classroom activities or through related online resources, the LO is numbered.

1953

Invention of High Level Programming Languages

1958

Integrated Circuits

1973

Mobile Phones and Interconnected Computers

1977

First modern PC - Apple II

1983

The World Wide Web



Grace Hopper and the UNIVAC

In the early years of computing technology, electronic computer could only be programmed by numbers, tape, punch cards or even manually manipulating the thermionic valves (vacuum tubes) to certain settings. After World War II, [Grace Hopper](#) worked on the first commercial computer called the UNIVAC. In 1953 she invented the first high level programming language, A-0, that used words and expressions to program the UNIVAC. She also created the first modern day compiler and coined the phrase BUG. A-0 evolved into

Flow-matic and eventually became the widely used [COBOL](#). Here are some lines of COBOL:

```
PROCEDURE DIVISION.
    LCCS-FIRST-PARA.
    DISPLAY 'Hello World.'.
    MOVE 'Grace Hopper' TO WS-NAME.
    DISPLAY 'My name is: ' WS-NAME.
STOP RUN.
```

The output will display

```
Hello World.
My name is: Grace Hopper
```

In 1954 IBM designed FORTRAN (FORMula TRANslation) which becomes an industry standard, especially in the area of scientific analysis. An IBM team led by John Backus developed the language which is still in use today. Here are some lines of FORTRAN:

```
DO
    a = SQRT(b) + c
    IF (a > z) THEN
        !// Exit the loop (comment)
        EXIT
    END IF
END DO
```

📺 Watch 2 jargon buster videos from a 1983 TV series Bits and Bytes.

[1.What is the difference between a compiler and an interpreter?](#)

[2.Explanation of High Level Languages.](#)

What would you add to the list at the end of the languages video?

LO 2.4

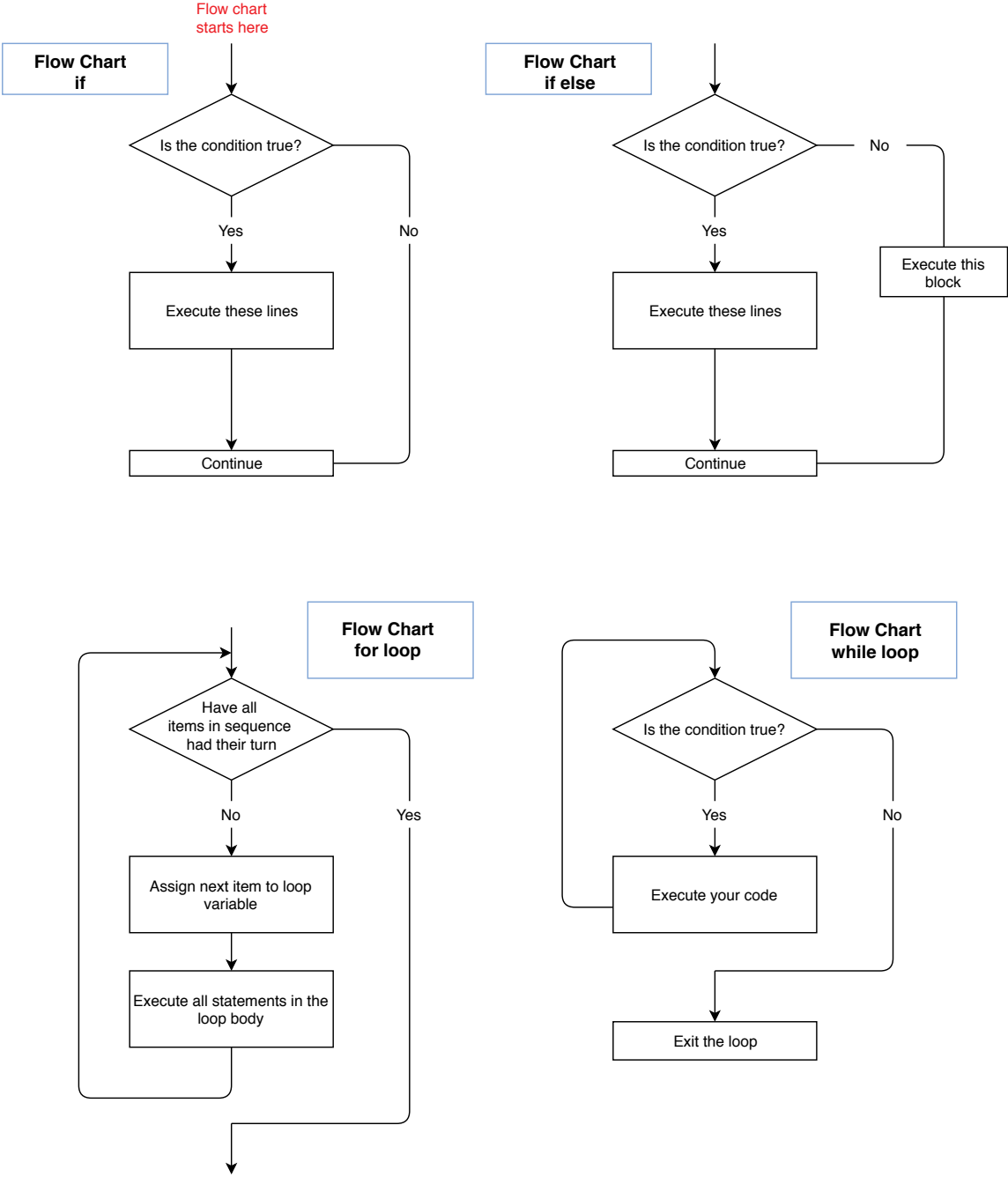
- [From Flow-matic \(1950s\)](#)
- [To FORTRAN \(1950s\)](#)
- [To BASIC \(1964\)](#)
- [To LOGO "Turtle" \(1967\)](#)
- [To Pascal and C \(1970s\)](#)
- [To Perl and Mathematica \(1980s\)](#)
- [To Java, Javascript, Swift, PHP, Python and Scratch \(1990s and beyond\)](#)

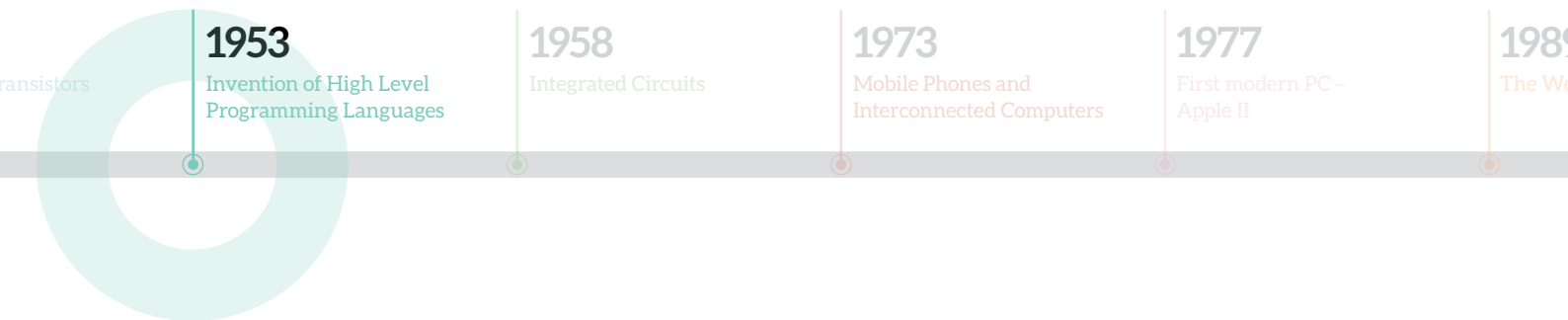
Explore the timeline above.

📺 Watch a video on [getting Y2K ready - BUG hysteria or good preparation on NY eve 1999?](#)

LO 1.11, 1.12

This example shows many similarities to the structure of most high level languages and scripting languages such as Python and Javascript. One of the features of Grace Hopper's flowmatic programming language was a conditional called an IF statement. The flow charts below illustrate decision-making algorithms now common place in high level languages: conditionals and loops.





In 1964, BASIC (Beginners All purpose Symbolic Instruction Code) was invented by two Maths professors, Kurtz and Kemeny. They designed their language specifically for learners. A decade or so later it was embedded on the earliest forms of personal computers mainly due to its adoption by a then little-known start-up called Microsoft. An example of the Hello World program in BASIC is below. (REM signifies a comment.)

```
10 REM Hello World in BASIC
20 PRINT "Hello World!"
```

The [Hello World website](#) demonstrates the introductory Hello World program in almost 600 programming languages.

To explore in further detail, the [CS Field Guide to Programming Languages](#) is an interactive, uncomplicated yet comprehensive introduction to this area, with some insightful interactive examples on [low level languages](#), including machine code, and also interpreted languages such as [Python](#). The Guide also explores [ASCII and Unicode](#) (UTF-8, UTF-16, UTF-32) in depth, including exercises on converting text to ASCII and Unicode, the limitations of using only 7 of the 8 bits in ASCII, and how to represent the word for cat, in Chinese. (LO 2.17)

High level languages are an abstraction from lower level languages. The programmer does not need to know what is going on below the level of the language, never mind at the lowest level of ones and zeroes. In this sense it seemed inevitable that programmers would need to be facilitated in writing programs that resembled spoken languages more than they resembled machine code.

The **innovation to use a keyboard** to enter data and construct programs, revolutionised the world of computing, as far back as 1956. "At MIT, researchers begin experimenting with direct keyboard input to computers, a precursor to today's normal mode of operation. Typically, computer users of the time fed their programs into a computer using punched cards or paper tape. Doug Ross wrote a memo advocating direct access in February. Ross contended that a Flexowriter – an electrically-controlled typewriter – connected to an MIT computer could function as a keyboard input device due to its low cost and flexibility. An experiment conducted five months later on the MIT Whirlwind computer confirmed how useful and convenient a keyboard input device could be." ⁷

Is it a matter of time before a virtual, or laser, keyboard becomes the normal means of keyboard interface? It is very interesting to discuss the impact of keyboard input on the world of computers and the advance of computing technologies. Is it an exaggeration to say that keyboard input has revolutionised our world and democratised the world of computer programming?

⁷ [computerhistory.org](http://www.computerhistory.org)
<http://www.computerhistory.org/timeline/computers/#169ebbe2ad45559efbc6eb35720ba5f3>

[Take the Crash Course on programming languages](#)

From the Crash Course Series on YouTube (Carri Anne Philbin)

LO 1.18
LO 2.4

There are more resources and exercises on [ncca.ie](#) related to this area.

Download the [CT challenge](#), which uses standard ASCII/utf-8 code to implement a basic Caesar shift encryption in Python, housed within a html file. Note that the head of the html file refers explicitly to the utf-8 character set.

LO 1.22, 1.23
LO 2.5-2.7, 2.19

Discuss the impact of keyboard input on the roles and careers in computers. How has it helped to spread digital literacy? Can you see a world where there is direct input to a computer, making the keyboard redundant?

Facilitate a Walking Debate on the above questions and/or TPSS activity on this area.

LO 1.13, 1.18

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Invention of High Level Programming Languages

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1977

First modern PC - Apple II

1980

The World

The journey of the letter Q from the keyboard to processing is many ways the same now as it was in 1956. But only at an abstract level. Follow the journey below from the moment you press the letter Q on your keyboard to its apparently instantaneous appearance on your screen. (Well most of the time!)

Join the Q!

1. YOU PRESS Q

The keyboard sends a signal (scancode) to the keyboard controller saying a button has been pressed.

2. PATIENT KEYBOARD CONTROLLER

Reads the scancode, sees the letter Q and stores it until the processor is ready.

3. IMPATIENT KEYBOARD CONTROLLER

Alerts the computer's processor (an [interrupt](#)) that it has input.

4. BUSY PROCESSOR

You can imagine the processor is quite busy. When it is ready to deal with a keyboard interrupt, it alerts the Operating System (OS)

5. MULTI - TASKING OS

The OS locates the window you were working in when you pressed the letter Q.

6. UPDATE WITH YOUR LETTER

Let's say, for example, you are in a word processing application, like notepad or MS Word. It adds Q to the working area of your file.

7. 1 BYTE OF THE Q

Q takes up 1 byte of memory. (8 bits of [Unicode](#) or 7 (used) bits of [ASCII](#))

8. LET THE OS KNOW

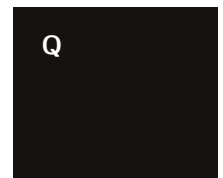
The window tells the OS to display Q. The OS obliges by adding it to the video card memory.

9. ON THE NEXT REFRESH, Q APPEARS

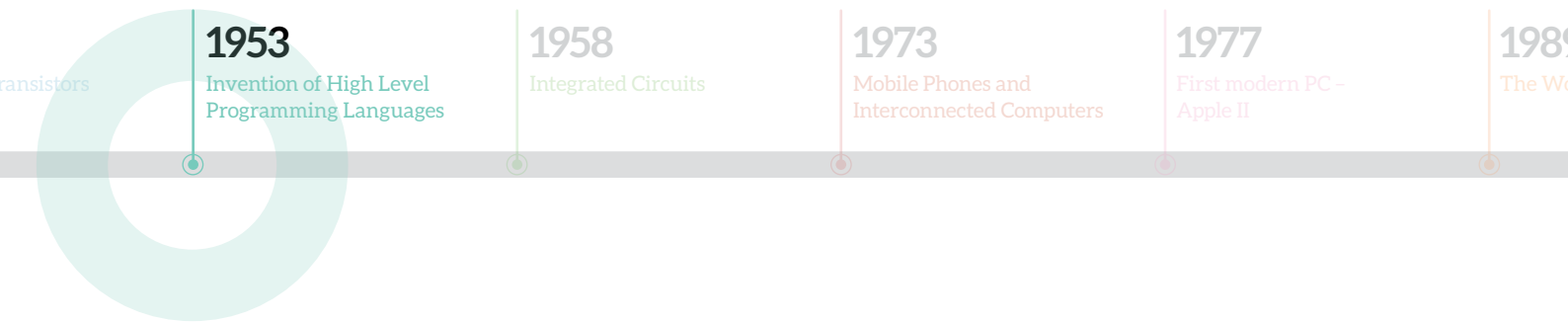
Monitors tend to be refreshed over 60 times per second.



YOU PRESS



YOU SEE



Computer science has created careers, roles and employment for people that we could never have imagined. A browse on the web of the most sought after skills in the digital hi-tech industry will most likely include: Software Engineer, Cloud Architect, CS Analyst, Data Scientist and Web Developer. Picture yourself in 1977, at the launch of Apple II, arguably the first modern PC. Could even visionaries such as Steve Wozniak and Steve Jobs have foreseen that careers in the CS industry would include Web Developers or Cloud Architects? With neither a spider nor a meteorologist in sight! However the first decades of the 21st century saw the rapid expansion of AI and cloud computing. It prompted many thinkers and leaders such as US President Barack Obama to question whether the digital revolution will be the first industrial revolution in history to be a net destructor of jobs as opposed to a net creator of jobs.

The World Economic Forum did a major report on The Future of Jobs.

Review their findings on [employment trends](#) and the disruptive effect of new technologies.

LO 1.18



Stimulate a Debate on how computer science is changing our world.

The model for this activity is explained in [A Summary of Teaching & Facilitation Methodologies](#).

1. Watch a Stimulus Video or read a stimulus piece.

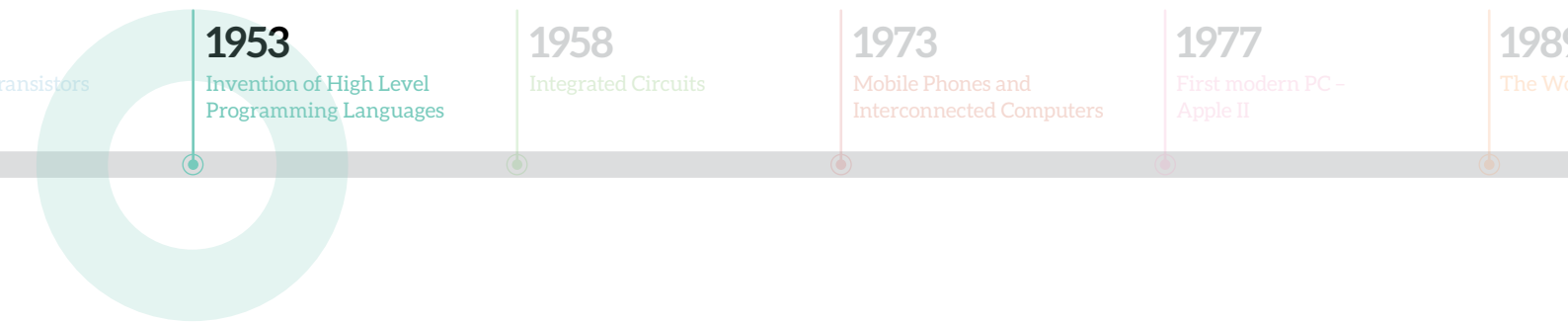
- ▶ [How CS is changing our world](#) is a video overview of new careers and opportunities opening up.
- ▶ The first 8 minutes of the BBC video [Will Robots Take Our Jobs](#), examines the impact of automated ports, focusing on Rotterdam. The remaining 20 minutes discusses the wider impact of CS on our world of roles and careers.
- ▶ The following piece is from Michael Dertouzos, speculating on the impact of CS on our world in the future. It was 1995, and he had just come from a meeting in MIT, chaired by the Tim Berners-Lee, the inventor of the world wide web.

“In a quiet but relentless way, information technology would soon change the world so profoundly that the movement would claim its place in history as a socioeconomic revolution equal in scale and impact to the two industrial revolutions. Information technology would alter how we work and play, but more important, it would revise deeper aspects of our lives and of humanity: how we receive health care, how our children learn, how the elderly remain connected to society, how governments conduct their affairs, how ethnic groups preserve their heritage, whose voices are heard, even how nations are formed. It would also present serious challenges: poor people might get poorer and sicker; criminals and insurance companies and employers might invade our bank accounts, medical files, and personal correspondence. Ultimately, the Information Revolution would even bring closer together the polarized views of technologists who worship scientific reason and humanists who worship faith in humanity. Most people had no idea that there was a tidal wave rushing toward them.”⁸

⁸ Dertouzos (1998) *What Will Be* HarperCollins.

LO 1.11

Students should be able to discuss the complex relationship between computing technologies and society including issues of ethics



1953

Invention of High Level Programming Languages

1958

Integrated Circuits

1973

Mobile Phones and Interconnected Computers

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1980

The World Wide Web

2. Prompt questions to provoke class discussion and elicit initial viewpoints.

Rasmussen college [pose 6 ways in which Computer Science improves the world we live in today](#). Do you agree that the evolution of computing technology has been only positive in the 6 areas below?

1. Solving problems and improving solutions
2. Protecting people and organisations
3. Furthering education
4. Improving communication
5. Organizing & streamlining philanthropy
6. Positively impacting every area of society

3. Divide into research groups to explore the topic from key standpoints.

If feasible, form at least 6 groups based on the 6 categories above. Each group examines one of the prompts above, analysing the particular standpoints below or researching the questions posed below. (The list of 6 prompts is suggestive and ideally adapted in an appropriate manner for the students)

For example, for prompt number 4. Improving communication, research the following:

- ▶ Is CS a net creator or destroyer of jobs in this area?
(Give an overview of the type of jobs created or destroyed and justify your conclusions)
- ▶ How has CS helped to improve our world in this area?
- ▶ How has CS helped to disimprove our world in this area?

4. Choose a teaching / facilitation methodology.

Adapt appropriately for your CS classroom.

- a. Students first research each topic in research groups of 3.
- b. Use a *Jigsaw Learning Technique* to create groups of 3 comprising one student from 3 different themes. Each person discusses their research within their new group.
- c. Reassemble into original groups.
Each group has up to 5 minutes in the *Hot Seat*
OR
A *Power of Persuasion* technique is used to group students into their preferred category and try to convince other students over to their viewpoint.
OR
A *Think-Pair-Share-Snowball (TPSS)* exercise to broaden out the findings and conclusions of each research group.

LO 1.12

Students should be able to compare the positive and negative impacts of computing on culture and society

1953

Invention of High Level
Programming Languages

1958

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1973

Mobile Phones and
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1977

First modern PC -
Apple II

1980

The W

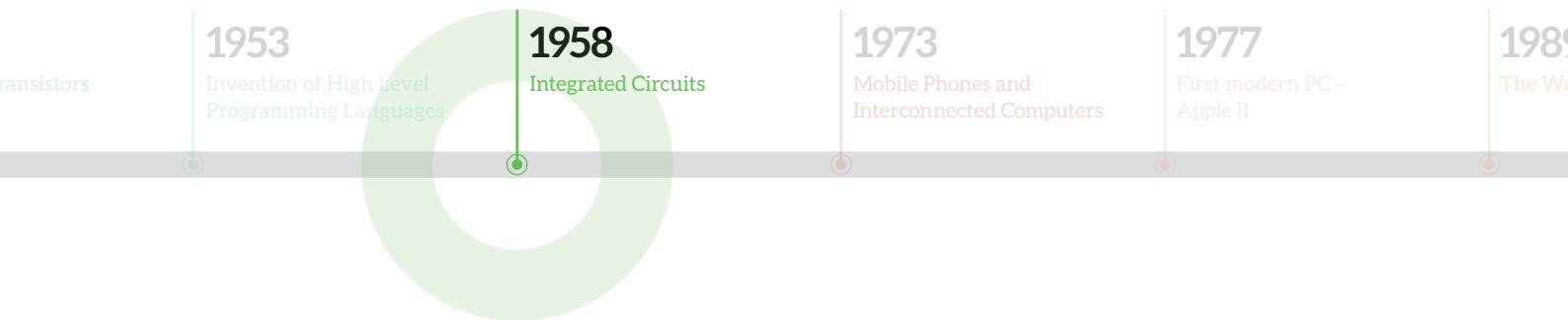
1958

Integrated Circuits

Learning Outcomes addressed in this section are listed below.

-
- 1.2** explain how the power of computing enables different solutions to difficult problems
-
- 1.13** identify important computing developments that have taken place in the last 100 years and consider emerging trends that could shape future computing technologies
-
- 1.14** explain when and what machine learning and AI algorithms might be used in certain contexts
-
- 1.18** recognise the diverse roles and careers that use computing technologies
-
- 2.3** implement modular design to develop hardware or software modules that perform a specific function
-
- 2.4** illustrate examples of abstract models
-
- 2.11** describe the different components within a computer and the function of those components
-

When other Learning Outcomes are addressed, for instance in classroom activities or through related online resources, the LO is numbered.



The invention of the first programmable, electric computers (Z1, ENIAC and Colossus), it could be argued, was the first time that high level human thought processes were offloaded to machines which could execute these processes both quicker and better. These computing machines provided proof of concept that computers could revolutionise the way humans think about solving problems. For the first time in human history, the question could now be posed – **How do I go about solving a particular problem, knowing I have the additional processing power of a computer at my disposal?**

After World War II, the invention of the solid state transistor almost immediately supplanted the unreliable vacuum tubes used in the first computers. In addition to predictable and reliable behaviour, they opened the floodgates of semiconductor design. No longer would an entire room be required to house all the distinct, discrete components of a computer. Suddenly the possibility of a completely functioning circuit, comprised of many electronic components on a single semiconducting platform, was a real possibility.

Integrated Circuits (IC) were invented in 1958 by electrical engineers [Jack Kilby](#) (Texas Instruments) and [Robert Noyce](#) (Fairchild Semiconductor). Like many inventions and ideas that have changed our world, their inventions were independently discovered. The drive behind the development of IC was very simple: how can we squeeze more components into a smaller space, at reduced cost and operating at faster speeds? The answer lay in the properties of semi-conducting elements such as Germanium and Silicon. Normally they behave as insulators, in the sense they do not conduct electricity. However using a chemical process known as doping, these substrates can become both conductors and insulators, depending on the conditions applied. There are only two types of doping: n-type doping makes the substrate richer in electrons and p-type doping makes the substrate depleted of electrons. When n-type and p-type are joined together, and a certain voltages applied across the junction where they are joined, [the basic ingredients of all micro-electronic semi-conducting devices can be assembled into diodes, transistors, logic gates, memory and microprocessor systems.](#)

Kilby eventually received the Nobel Prize in 2000 for his work, where he acknowledged the now deceased Noyce as his co-inventor. Noyce founded the Intel Corporation with [Gordon Moore](#) in 1968. They released the first microchip computer or microprocessor in 1974, paving the way for the first modern Personal Computers.

“Thinking like a computer scientist means more than being able to program a computer. It requires thinking at multiple levels of abstraction.”⁹

The above quote is from Jeanette Wing’s highly [influential paper on Computational Thinking](#). Using TPSS, discuss the origins of Computational Thinking in the context of the evolution of computers.

LO 1.2

1. [A fast-talking technical overview of the development of IC and how Moore’s Law might be re-imagined.](#)
2. [An animated overview of the limits of IC technology and the potential of Quantum Computing.](#)

In the section on the Turing Machine, the explosion in AI was attributed to Data, Algorithms and Processing Power.

Would you agree with this hypothesis?

LO 1.13

⁹ Wing (2006) *Computational Thinking Commun ACM* 49 (Carnegie Mellon University) .

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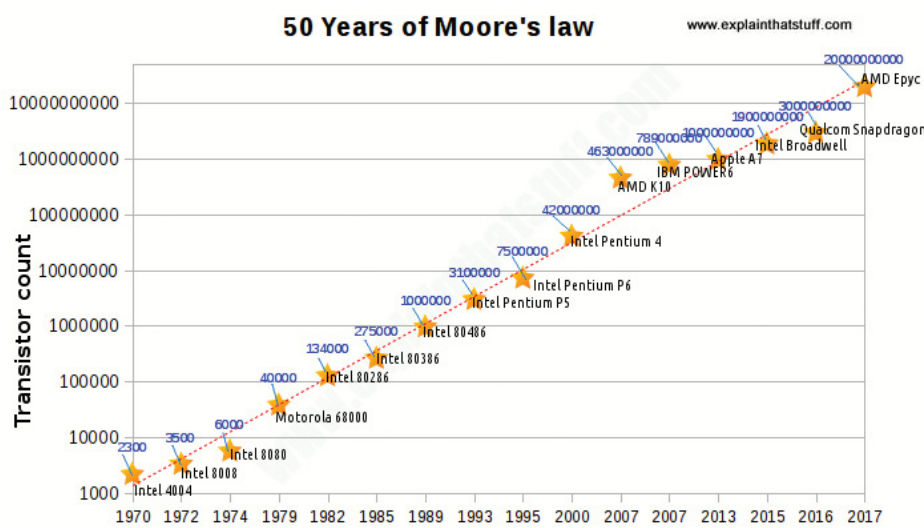
The World

Moore's Law is one of the most famous laws in the world of computer science. The graphic below is from www.explainthatstuff.com. Moore's Law says that the number of transistors on an IC will approximately double every 2 years. Thus the processing power of computers will also double approximately every two years. Moore's Law is more of an observation/prediction than a scientific law. As can be seen by the graphic below, it has been extremely accurate.

▶ [Take the Crash Course Video on Integrated Circuits \(0.00-9.00\) and Moore's Law \(9.00-12.30\)](#)

From the Crash Course Series on YouTube (Carri Anne Philbin)

LO 2.3, 2.11



But can the size of transistors continue to decrease from microns (a millionth of a metre) into the realm of nanometres (a billionth of a metre)? The state of current IC technology is often called process. In the table below a 4 micron (μm) process refers to the length of the transistor gate.

Remember the width of a human hair is in the range of 80-100 μm .

Processor	Transistor Count	Year	Process	Comparable Objects	Electromagnetic Spectrum
Intel 4004	2300	1971	10 μm	Red Blood Cells	Infra Red
Motorola 68000	68000	1979	4 μm	Most bacteria	Infra Red
Intel 80486	1.18 million	1989	1 μm	E-coli	Visible Light 0.4-0.7 μm
Pentium III	9.5 million	1999	250 nm	Pollen, Viruses	Approaching UV light
Six Core i7/8	2 billion+	2011	32nm	Molecules	UV light
Exynos 8895	20 billion+	2017	10nm	50 atoms of Silicon	Soft X-rays are 1nm

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The latest innovations are a 5nm process. This has often been considered the limit for Moore's Law because it is a mere 25 atoms in width and effects such as current leakage and [quantum tunnelling](#) have to be overcome. It is not surprising therefore that IC technology as we know it is evolving given that humans are now engineering material at similar widths to a DNA molecule.



Stimulate a Debate on how should we respond as a society to the rapid growth of Artificial Intelligence (AI)

The model for this activity is explained in [A Summary of Teaching & Facilitation Methodologies](#).

1. Watch a Stimulus Video or read a stimulus piece.

In the section on Turing Machines, a short video, on [classical versus quantum computers](#), explored the limits imposed by Moore's law and the possibilities opened up by quantum technology. In addition the rapid growth in AI and machine learning was looked at through the lens of data, algorithms and of particular relevance in this section, processing power. ([Why this seemingly sudden explosion?](#)) And what about the ethical implications of the increased automation of human skills and processes? Watch a snippet (10:30-19:49) of a [TED talk featuring renowned machine learning expert Jeremy Howard](#) from 2014. The automation of clinical medical analysis, which has already surpassed the best specialists in the world, is advancing rapidly with both positive and negative impacts on society. Make a note of how he defines services and the overlap between services and machines learning to do things under supervision. Why does he think the Machine Learning revolution is different from the Industrial revolution in terms of how it will impact society?

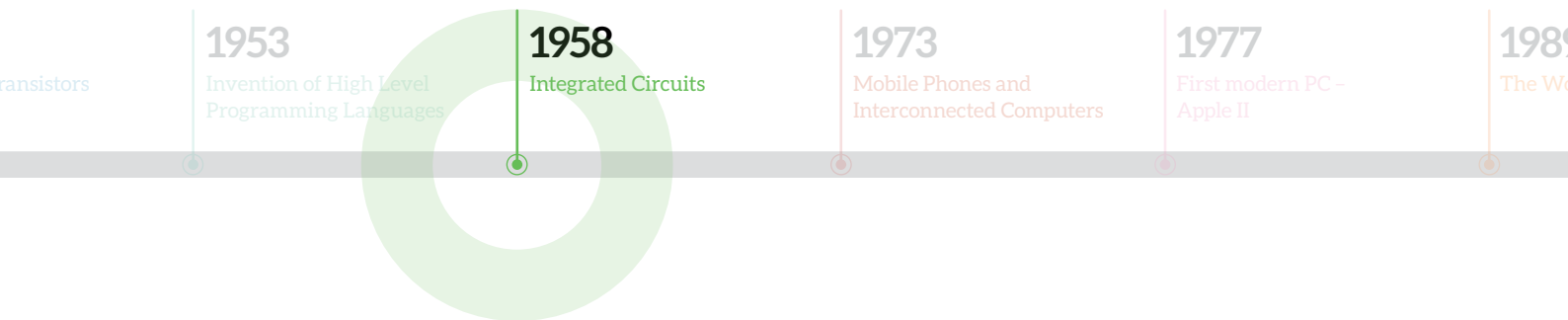
[Watch a BBC Click video \(7:30 - end\)](#) that discusses a range of opinions on how society should change its structures to adjust to the advances of AI. For example, if the diversity of jobs decreases, should we consider universal income for all?

Is this a good time to check the growth of AI? When we call a hotel to make a booking, are we entitled to know if we are speaking to a human or machine?

The Human Brain Project is attempting to understand what each section of the human brain does and how our brains work.

▶ Watch this 90 seconds video on their webpage showing the [multi-scale dimensions of the brain](#), from centimetres to nanometres.

LO 2.4



2. Some prompt questions to provoke class discussion and elicit initial viewpoints.

- ▶ The service industry in the developed world accounts for about 80% of employment. From waiters to doctors to accountants, they need to learn how to work with AI in order to thrive. If the services industry does not embrace this technology, will the technology consume the services industry?
- ▶ The developing world can save billions in money and in lives by embracing automated services. For example in the area of training doctors or solicitors. Should the training be how to work with and supervise AI as much as learning how to work with patients?
- ▶ As the wealth generated by AI increases, and the wealth generated by humans decreases, should we re-structure the relationship between the citizen and the government? For example, should there be a universal income for all citizens? Should health and well-being technology be mandatory for all humans to save on health care and social welfare payments?

3. Divide into research groups to explore the topic from key standpoints.

Themes for different groups:

- ▶ The growth of AI and machine learning has an overall positive impact on society and on technology.
- ▶ The growth of AI and machine learning has an overall negative impact on society and on technology.
- ▶ Societies, both developed and developing societies, must change their structures to accommodate the disruptive effect of AI.
- ▶ Societies, both developed and developing societies, must limit the impact of AI to accommodate the needs of their societies.

4. Choose a teaching / facilitation methodology.

Adapt appropriately for your CS classroom.

- a. Students first research each topic in research groups of 3.
- b. The teacher uses a *Jigsaw Learning Technique* to create groups of 3 comprising one student from 3 different themes. Each person discusses their research within their new group.
- c. Reassemble into original groups.

Each group has up to 5 minutes in the *Hot Seat* OR

A *Think-Pair-Share-Snowball (TPSS)* exercise to broaden out the findings and conclusions of each research group.

OR

A *Power of Persuasion* technique is used to group students into their preferred category and try to convince other students over to their viewpoint.

LO 1.12

Students should be able to compare the positive and negative impacts of computing on culture and society

LO 1.18

Students should be able to recognise the diverse roles and careers that use computing technologies

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Learning Outcomes addressed in this section are listed below.

-
- 1.8** evaluate the costs and benefits of the use of computing technology in automating processes
-
- 1.11** discuss the complex relationship between computing technologies and society including issues of ethics
-
- 1.12** compare the positive and negative impacts of computing on culture and society
-
- 1.13** identify important computing developments that have taken place in the last 100 years and consider emerging trends that could shape future computing technologies
-
- 1.15** consider the quality of the user experience when interacting with computers and list the principles of universal design, including the role of a user interface and the factors that contribute to its usability
-
- 1.16** **compare two different user interfaces and identify different design decisions that shape the user experience**
-
- 1.17** describe the role that adaptive technology can play in the lives of people with special needs
-
- 1.18** recognise the diverse roles and careers that use computing technologies
-
- 2.15** explain what is meant by the World Wide Web (WWW) and the Internet, including the client server model, hardware components **and communication protocols**
-

When other Learning Outcomes are addressed, for instance in classroom activities or through related online resources, the LO is numbered.

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At the launch of the iPhone in 2007, Steve Jobs, CEO of Apple, claimed to have re-invented the phone. In many ways Apple did re-invent our idea of a phone by enabling the phone to access all modes of communication, from voice to email to text to internet connectivity.



In 1973 Martin Cooper, a Motorola researcher, made the first ever call on a mobile phone. As you can see in the picture, mobile phones were a lot larger in size than today's handsets. His first call was on a device weighing in excess of 1 kg. This event was every bit as momentous as Alexander Graham Bell's first patent for a telephone in 1876.



Bell built upon advances in telegraphy, among them Samuel Morse's famous system of communication. For the following 100 years, a phone was essentially fixed to a landline. You, the user of the phone, had to be physically beside the location of the phone. The concept of a phone being as mobile as the user, with the only restriction being the strength of a signal, revolutionised our idea of communication. In America the [mobile phone](#) became known as a cell phone, because the local networks were called cells.

The following quotes are from Alexander Graham Bell, accredited with inventing the telephone.

"The day will come when the man at the telephone will be able to see the distant person to whom he is speaking."

"I truly believe that one day, there will be a telephone in every town in America."

Check out some [predictions about mobile phones](#) beyond 2020. Which ones do you think will become standard?

Watch a [video of 10 examples](#) of how hard it is to predict technological advances or measure the impact of current technology.

LO 1.12, 1.13, 1.18



Brain Buster

The limitations on the size of early mobile phones were due to the technology. It was not possible, at that time, to manufacture smaller handsets. Today the limitation on the size is determined less by the technology and more by what is practical for an average human. As the manufacturing process shrinks to the atomic and cellular level, should our phones shrink to the same level so they can be embedded within the person's body? It might give new meaning to the word cellphone!

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🔧 Classroom Communication Activity

To design your own system of communication or use an existing system to communicate within an LCN (Local Class Network!!!).

The activity requires a minimum group of 3 students. It can be an unplugged physical computing algorithm, a programmed solution using Python, Javascript, Scratch, Snap, etc., an embedded microprocessor system solution or a combination of ideas. Each solution must be robust and systematic, with evidence of computational thinking.

Below are some ideas for activities.


UNPLUGGED

- ▶ Using only a system of blinks, design a system for giving directions to a person or automata to exit any room or labyrinth. For example, construct a simple maze from which the person must be guided towards the exit. Remember behaviours such as the length of a step or the degrees of a turn must be pre-configured.
- ▶ [Morse code](#) was a hugely successful system of telegraphic communication from the mid 19th to mid 20th century. It is in many ways an early form of binary in the sense that all signals are either a dot (·) or a dash (-). The dash should last 3 times longer than the dot. The following letters are represented in the following way: M (- -) O (- - -) R (· - ·) S (· · ·) E (·). How would you signal SOS in Morse code? The dot and dash can be represented by light, by sound, or as suggested below in the plugged section, by strings sent over radio waves.
- ▶ In his book the [Diving Bell and the Butterfly](#), later a film, Jean-Dominique Bauby described his life with locked-in syndrome. How did he write the text? His method was to blink out each letter to a helper who transcribed it to paper. He used a system of frequency analysis. "E is the most common letter (in both English and French), for example. He therefore got the helper to read out the letters in order of how common they are: their frequency. In English, the order is "E..T..A..O..". In French, Bauby's language, it is "E..S..A..R.." ¹⁰. However there are other even more efficient ways to communicate in this fashion, in particular using binary search algorithms. The following [London School of Computing booklet](#) gives an excellent overview of this problem.

🔧 Communication Activity

This activity addresses a [vast number of LOs](#). In particular:

- ▶ *Computational Thinking* LOs in Strand 1 **(LO 1.1-1.10)**
- ▶ *Abstraction and Algorithms* LOs in Strand 2 **(LO 2.1-2.9)**
- ▶ *ALT3 Modelling and Simulation* LOs in Strand 3 **(LO 3.8-3.9)**

Stephen Hawking famously communicated through adaptive technology. As his Motor Neuron Disease (known as ALS in the US) progressively removed all physical movement,  [the technology advanced in parallel to ensure he could still communicate effectively.](#)

How would the advances in adaptive technology have helped Jean-Dominique Bauby (see unplugged activity) to write his book? Would it be a more efficient, but less personal experience for him?

LO 1.8, 1.17

¹⁰ Curzon P., McOwan P (2017) *The Power of Computational Thinking* World Scientific.

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PLUGGED

- ▶ Using a microprocessor, design a system to communicate remotely to another system. One system of communication could be Morse code or an adapted version of Braille. [Check out some other systems](#), including ciphers such as the Caesar cipher. Or communicate between 2 microprocessors using the serial ports. For example, the microbit serial communication mimics the 7 bit ASCII code referred to in a previous section.
- ▶ Use Python or JS to create basic communication systems within your group or perhaps an interactive webpage that uses html action forms or similar code, to allow communication within your LCN. (Local Class Network). Your group decides on the channel of information transfer, whether it is using emails, IP addresses, sms texts (if allowed under school policy), or a combination of unplugged and plugged communication systems.

In the same year, 1973, that the first call was made on a mobile phone, another concept that would eventually revolutionise the world became real and feasible: interconnected computers. The story behind the Internet begins much earlier. In 1957 the Soviet Union launched Sputnik, the first unmanned satellite in space. As part of the USA's response to this technological breakthrough, the US government set up the Defense Advanced Research Projects Agency ([DARPA](#)). Originally called ARPA, its aim was, and still is, to ensure the US stays at the cutting edge of technological advances.

"DARPA explicitly reaches for transformational change instead of incremental advances. But it does not perform its engineering alchemy in isolation. It works within an innovation ecosystem that includes academic, corporate and governmental partners, with a constant focus on the Nation's military Services, which work with DARPA to create new strategic opportunities and novel tactical options. For decades, this vibrant, interlocking ecosystem of diverse collaborators has proven to be a nurturing environment for the intense creativity that DARPA is designed to cultivate."¹¹



Stimulate a Debate on the role of the military, and in particular DARPA, in shaping some key technological developments in everyday society. (LO 1.11, 1.12)

In the 1960s, before the networking of computers, people could share a single computer by logging on to a terminal. They would then time-share the main computer. This multi-user approach spawned file sharing, emails and generally improved communication within the business, military and educational worlds. But only in a limited, localised fashion, generally known as Local Area Networks (LANs).

There are more resources and exercises on ncca.ie related to this area.

In the section on Lists and Dictionaries there is an advanced [CT challenge](#), which uses standard ASCII/utf-8 code to implement a basic Caesar shift encryption in Python, using a Tkinter UI and/or a simple txt file.

LO 1.22, 1.23

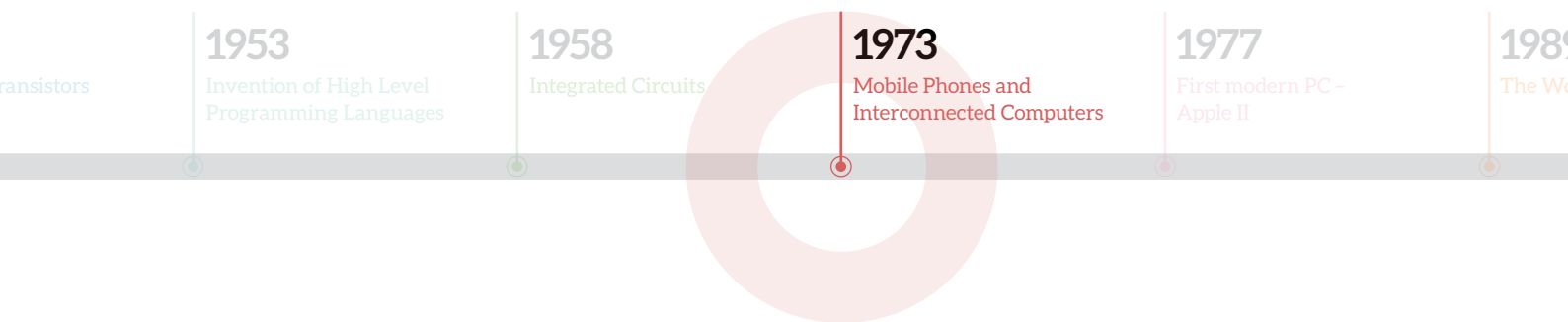
LO 2.5-2.7, 2.19

In the 1960s ARPA developed a system called NLS (oNLineSystem). Its pioneering [HCI](#) evangelist was [Doug Engelbart](#). In a now legendary "[Mother of all Demos](#)" in San Francisco in 1968, he stunned his audience with:

- ▶ Word processing of documents
- ▶ Windows on your working documents
- ▶ Collaborative online editing of documents
- ▶ Video Conferencing
- ▶ Hypertext links within documents
- ▶ The use of a new gadget he invented himself called a mouse!

LO 1.15, 1.16

¹¹ DARPA official site <https://www.darpa.mil/>



In the late 1960s, DARPA decided to connect scientists and engineers in 4 separate locations using a network of interconnected computers called the ARPANET. It was successfully launched in 1969, and within a couple of years other networks sprung up all over the world (NPL (UK), ALOHANET (a wireless system in Hawaii), HLN (an airline network), CYCLADES (France)). Because these networks developed in isolation, their methods of communication and packet switching were incompatible. The interconnection of networks became a key goal of industry and of military. The UK and France were the first to experiment with internetworking. However it was ARPA's [Transmission Control Protocol / IP](#), first sketched out in 1973 by Vint Cerf and Bob Kahn, which would come to dominate the landscape of information transfer. ARPA at this stage had several networks and in 1977 demonstrated that it could connect them all. This became known as the internet. [Lynn Root and Vint Cerf explain the operation of packets and TCP](#) in this code.org video.

1973 was also the year the ethernet was invented. At the time there were many standards for interconnecting computers such as IBM's Token Ring. But the ethernet is the one, looking back, that became the standard. The big question is often why some technologies endure and others simply fade away. In the age of wireless communication, and increasingly as devices do not have any method for direct ethernet connection, [watch a tech experiment to connect an iPhone to the internet using an ethernet cable](#).

[code.org](#) designed an internet simulator for the classroom. The activity is fully described in the section on the world wide web.

▶ Watch a [PICOL animated video on the History of the Internet](#), including DARPA's role. (subtitled)

The SciShow have a [history of the Internet](#), followed by History of the Web. (subtitled)

Some prompts for the above video lessons:

- ▶ The early form of the Internet was known as the ARPANET. Which colleges did it initially connect?
- ▶ What is Packet Switching, and why has it superseded Circuit Switching?
- ▶ Name other networks that formed and outline their contribution to the development of the internet.

LO 2.15

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First Modern PC – Apple II

Learning Outcomes addressed in this section are listed below.

-
- 1.7** develop algorithms to implement chosen solutions
-
- 1.11** discuss the complex relationship between computing technologies and society including issues of ethics
-
- 1.13** identify important computing developments that have taken place in the last 100 years and consider emerging trends that could shape future computing technologies
-
- 1.15** consider the quality of the user experience when interacting with computers and list the principles of universal design, including the role of a user interface and the factors that contribute to its usability
-
- 1.18** recognise the diverse roles and careers that use computing technologies
-
- 2.1** use abstraction to describe systems and to explain the relationship between wholes and parts
-
- 2.4** illustrate examples of abstract models
-
- 2.11** describe the different components within a computer and the function of those components
-
- 2.12** describe the different types of logic gates **and explain how they can be arranged into larger units to perform more complex tasks**
-

When other Learning Outcomes are addressed, for instance in classroom activities or through related online resources, the LO is numbered.

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A brief review

The first electronic computers, Colossus and ENIAC, weighed tons and occupied large rooms. The invention of solid state transistors and integrated circuits placed computer hardware on the exponential curve now known as Moore's Law. The reality from 1958 was that every 2 years or so, IC manufacturers could squeeze twice as many components into the same space, at reduced cost and operating at faster speeds. In addition software and UI design were accelerating at a phenomenal rate. For example, Hopper's invention of high level programming languages in 1953 or Engelbart's 1968 demo of windows on a screen, word processing and a mouse. By the 1970s, the microcomputer kit which the user assembled into their own casing, became very popular. One of the early examples of a microcomputer kit was the Altair 8080. In 1975 they teamed up with 2 software developers, Paul Allen and Bill Gates. That April, the two friends formed Microsoft.

What made the Apple II different

All of these hardware and software ingredients needed a visionary to bring them together for a mass market. In fact 2 visionaries were required. Steve Wozniak and Steve Jobs.

The Apple 1 was the first computer assembled on a single circuit board. However it was still a microcomputer kit, which the user housed in their own casing. Apple II revolutionised the concept of a computer through a mixture of innovative hardware design and a focus on user-centred design.



The first Apple was completed in 1976. It sold 175 units. Users had to build their own casing around it, like this wooden casing in the photo. Wozniak used 1970s state of the art Intel processors. Software (written by him in BASIC) was still quite limited as it had to be customised to the hardware.



The second Apple was completed in 1977. Inspired by modern electronic commodities such as TV and stereos, the modern PC had truly arrived. Apple produced a million units. Major corporations, such as IBM, were now being disrupted for the first time by small start-ups like Apple.

▶ Watch a short video on [the evolution of computing devices](#).

Some video prompt questions:

- ▶ What 4 features of the Babbage machine made it revolutionary?
- ▶ Name components that act as switches?
- ▶ What was the first microprocessor used for?

Explore the [Human Brain Project](#) website to see the latest advances in how our brains could be simulated.

LO 1.13

LO 2.1, 2.11

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Wozniak and Jobs, April 1, 1976

One of the biggest differences in the development of the first PC, compared to previous computing technology, was that it started up from the garages and homes of computer enthusiasts. Wozniak, seen on the left of this photo with Jobs, was a highly gifted engineer, but computer engineering was a pastime he pursued on his own and through his computer club. In many ways he was the original hacker. When he teamed up with Steve Jobs, the concept of a start-up company in a garage or a bedroom was born.

Steve Wozniak himself looks back at his invention of the PC.

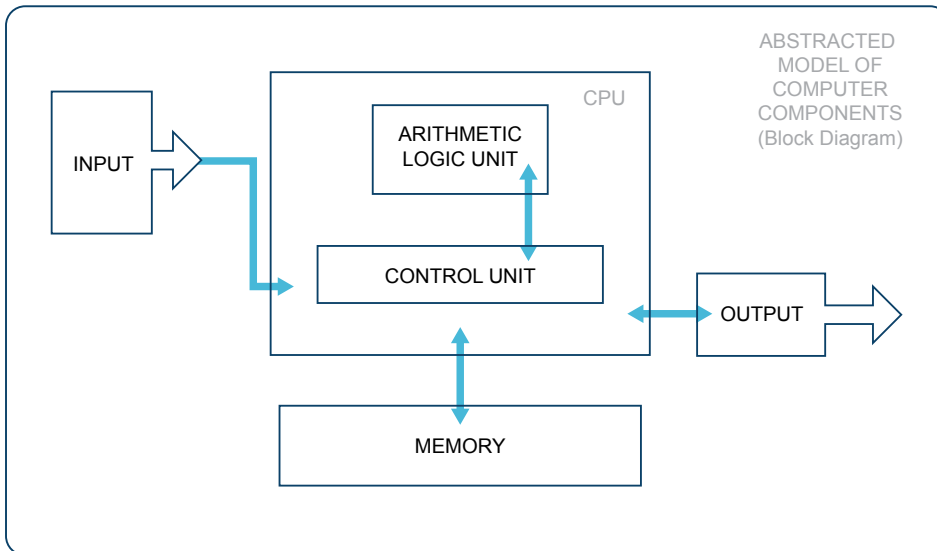
In this [intriguing 5 minute tour](#), from 1984, he explains his concept of a “portable computer” and how 1984 would be the year of the mouse!

[Later in 2014](#), he explains his innovations as part of a series on hi-tech companies disrupting the business world.

LO 1.13, 1.15
LO 2.11

Inside the computer

At an abstracted level, the modern computer has four components. Input, Output, Memory and Processing. For the modern computer, processing is done in the Central Processing Unit (CPU). It makes sense when describing CPU to describe the Arithmetic Logic Unit (ALU) and the Control Unit. The schematic diagram shows the five components.



- 1. INPUT** The keyboard and mouse quickly established themselves as the most effective input devices. Increasingly voice and visual images are forming an essential part of interaction with computing technology.
- 2. OUTPUT** Computer screens have been the most enduring physical devices associated with computers, with modern screens displaying at very high resolutions. The visual and audio output elements are becoming increasingly important. 3D Games require excellent graphics cards to function on PCs. It was once thought computers would bring in a paperless world. However, printers remain essential for outputting hard copies.

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3. **MEMORY** The hard drive of a computer is the name for the permanent (magnetic) long-term storage of vital information. We are now in Terabytes for most hard drives. Random Access Memory (RAM) is temporary short-term storage, while your computer is working. The Apple II had 24 kB of RAM. A good analogy is that RAM is what you need when sorting files on your desk and your hard drive is what you file away in your filing cabinet.
4. **ALU** The Arithmetic Logic Unit is an integrated circuit of logic gates, designed to carry out basic mathematical and logical operations. Most CPU operations are executed in the ALU. The inputs to the ALU are stored in specialised CPU memory called input registers. Once the calculations are performed, the results are stored in memory called output registers.
5. **CONTROL UNIT** The control unit controls the operation of the processor and tells all other components how to respond to the computer's instructions. A program counter is a specialised memory that keeps track of the order of instruction that a computer is executing. The dedicated bit of memory is called a processor register.

Operating System Layers

"The most important and crucial piece of software for a computer is its operating system (OS). The same hardware under a different OS is literally a different computer."¹² An OS is software that manages all other programs on a computer. The other programs are called application programs (apps). The OS handles the operation of the 4 abstracted components of a computer system: Input, Output, Processing and Memory. The interface between the application programs and the OS is called the Application Program Interface (API). The user can interact directly with the OS through the Graphical User Interface (GUI) or sometimes through the command line. An even more fundamental piece of software is the Basic Input Output System (BIOS). This acts as the interface between IO devices and the main OS. Because it is particular to the hardware of the machine, and comes pre-installed, it is often called firmware. Examine [another way of looking at OS layers](#).

The most common operating system on home PCs are Microsoft Windows and Mac OS. Corporate firms also commonly use Linux and UNIX OS.

¹² Wang (2016) *From Computing to Computational Thinking*. CRC Press (p 69-77).

Read the section on the five components of a computer. Then address the following.

INPUT Will the physical keyboard and mouse become obsolete?

Memory What is the RAM on the device you are using to read this?

Check out this [site explaining units of memory](#).

Is lots of memory on your PC so important, or even necessary, with the dominance of cloud computing?

ALU Review the operation of logic gates and how to build more complex arithmetic blocks.

LO 1.7
LO 2.4, 2.11, 2.12

A [brief history of computers](#) provides more detail on how

- ▶ Apple II evolved
- ▶ Intel and Microsoft established dominance in the market (and Kildall didn't!)
- ▶ Steve Jobs started a user revolution in the late 1980s, starting with the Mac OS GUI.

LO 1.11, 1.15
LO 2.11

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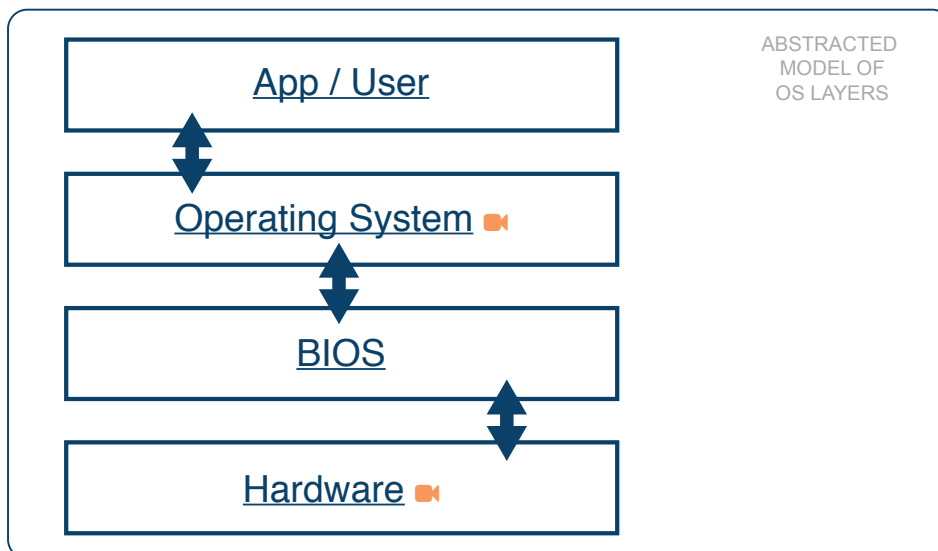
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Why have an OS?

Computers simply cannot function without the coordination and resource management offered by an OS. The software in the first PCs had to be customised to the specific hardware design. This meant that a user's programs could not operate on a different computer. In 1976 Gary Kildall, from the same computer club as Wozniak, had an idea to put a system between the user and hardware. This Operating System could run the user's programs and also communicate with the hardware design. Because the OS can communicate with the hardware design of any machine of similar make, then the user can run their programs on any machine. This is crucial for programmers, business and general home users.



Click the links on each OS layer to watch a *video* (OS and Hardware) or *read some more* (App/User and BIOS)

Videos are from [techquickie](#) and [code.org](#).

The *read some more* articles are from the [CS Field Guide](#) and [Wikipedia](#).

LO 1.15

LO 2.1, 2.4, 2.11

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The World Wide Web

2000–2020

Cloud Computing
and the Smart Phone

Emerging trends
in the 21st century

1989

The World Wide Web

Learning Outcomes addressed in this section are listed below.

-
- 1.11** discuss the complex relationship between computing technologies and society including issues of ethics
-
- 1.12** compare the positive and negative impacts of computing on culture and society
-
- 1.13** identify important computing developments that have taken place in the last 100 years and consider emerging trends that could shape future computing technologies
-
- 1.18** recognise the diverse roles and careers that use computing technologies
-
- 1.22** read, write, test, and modify computer programs
-
- 2.15** explain what is meant by the World Wide Web (WWW) and the Internet, including the client server model, hardware components **and communication protocols**
-

When other Learning Outcomes are addressed, for instance in classroom activities or through related online resources, the LO is numbered.

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The World Wide Web

2000–2020

Cloud Computing
and the Smart Phone

Emerging trends
in the 21st century

The world wide web, was invented by Tim Berners-Lee while working at the CERN laboratories in Switzerland. “The things that happened with the web blow us away, they are much more than we originally imagined. ...There is still huge unlocked potential”¹³ Originally invented as a means of sharing research and data, the web has transformed itself into a vital part of all our lives, transforming our lives in the process. The Internet and the world wide web are not the same thing.

The Internet is a global network that connects computers and computer networks. The linking of computer networks is called internetworking, from which we get the name internet. The communication system governing this global network is known as Internet Protocol (IP). The Internet evolved from a US military project in the late 1960s known as ARPANET, from which IP and other protocols (TCP, UDP) evolved.¹⁴

The World Wide Web is the information space that can be accessed by the Internet. Resources on the web are requested and retrieved by **uniform resource locators** or URLs. A URL is usually in the form:

scheme://serverhost:port/pathname?query_string

The *scheme* indicates the protocol (*http* is the default scheme, *https* is the more secure protocol)

serverhost is the domain name or IP address (A [DNS](#) is a Domain Name Server or System whose job is to convert human-friendly domain names into internet-friendly IP addresses. It is in essence a database.)

port and *pathname* are optional and seldom included in modern usage.

HTML stands for HyperText Markup Language, and was invented by Tim Berners-Lee. <start tag> A file written in html contains text and content (videos, images, etc..) interspersed with <*begin tags*> and </end tags> . The tags allow the content to be easily read and formatted by any Web Browser (explorer, firefox, chrome, etc..). </end tag>. Each programming concept on the NCCA website contains a Computational Thinking Challenge written on a html platform, designed to be edited by teachers and students.

▶ Watch [Tim Berners-Lee TED talk from 2009](#) and answer the following prompts.

- ▶ Who is Hans Rosling?
- ▶ What are TBL's 3 rules for using the web?
- ▶ What is linked data?
- ▶ What is Database Hugging?

LO 1.13, 1.18

[An overview of a Lesson Plan on the Internet using code.org.](#)

You can sign up your class to view these lessons on the Internet.

Follow [the setup instructions](#), including a ▶ [video](#) on how it works, to create an Internet Simulator, as part of the code.org lesson plan.

LO 2.15

[Facilitate a walking debate on Tim Berners-Lee quotes.](#)

For example:

“I think in general it's clear that most bad things come from misunderstanding, and communication is generally the way to resolve misunderstandings, and the Web's a form of communications, so it generally should be good.”

LO 1.13

[Open the html demonstration file for CT Challenges in section 0 of Programming Concepts on the ncca website.](#)

Visit [ncca.ie](#) Computer Science

LO 1.22

¹³ https://www.ted.com/talks/tim_berniers_lee_on_the_next_web#t-225527

¹⁴ Wang (2016) *From Computing to Computational Thinking* CRC Press.

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Computer Network Protocols

Think of how many different types and brands of computers you can buy, and then think of all the different Operating Systems working on those computers. For these computers to communicate over the network they have to agree rules and conventions known as Network Protocols.

The OSI (Open System Interconnect) model of networking layers provides a standard view of how protocols operate. The table below shows how TCP/IP maps against the OSI layers. TCP/IP is the dominant protocol.

The TCP/IP and OSI Models of Networking Layers

TCP / IP	OSI Layers		Example Protocols
Application	Data	Application Transfer html to your computer	http, dns
	Data	Presentation Format the data (Network Translator)	SSL
	Data	Session Coordinate different processes	NetBIOS
Transport	segments	Transport Reliable end to end Transfer	TCP, UDP
Internet	packets	Network Determine physical path data takes	IP
Network Interface	frames	Data Link Physical Addressing	PPP, Ethernet
	bits	Physical Media and Binary Transmission	USB, Bluetooth

[A brief introduction to Network Communication Protocols.](#)

From the CS Field Guide (Tim Bell)

LO 2.15

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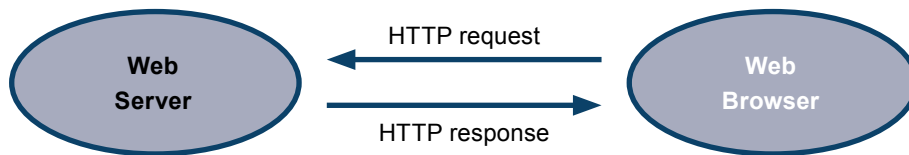
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The design of network protocols is an important area of computer science. Note in particular the following ideas and examples.

Client Server Model When you email or video conference or browse the web, the network service you are using involves a client program (MS Outlook, Google Chrome, etc) communicating on your behalf with a server program running on a specific host.

HyperText Transfer Protocol (HTTP) Web browsers and web servers communicate using this protocol. Its job is to transfer hypertext, like html, to your computer.



Internet Protocol (IP) Addresses In the lower layer of the OSI model, every host will have its own network address that identifies the host (usually your computer) for communication purposes. A typical IP address would look like 83.141.127.255. This is an IPv4 address. It is made up of 4 bytes. In binary it is 32 bits and would be 01010011 10001101 01111111 11111111. The rapid expansion of the Internet is now accommodated by IPv6, which supports 128 bit addresses.

Transmission Control Protocol (TCP) is the transport layer that ensures data arrives reliably. The system of handshakes, ordering and acknowledgement that data has arrived, trades off speed for accuracy. Given the number of nodes (computers, [routers](#), etc..) that packets of data must go through, data inevitably gets delayed or corrupted by interference. Play the Packet Attack Game to see why TCP is the most commonly used transfer protocol on the internet.

📺 [Take the Crash Course Video on Computer Networks including ethernet.](#)

From the Crash Course Series on YouTube. Leads on to the Internet and WWW. (Carri Anne Philbin)

LO 1.12
LO 2.15

[Play the Packet Attack Game which goes through 7 levels of Transfer: A simulation of TCP and why it is virtually impossible to stop level 7 TCP.](#)

From the CS Field Guide (Tim Bell)

LO 2.15

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Classroom Experiment

It is quite straightforward to see how data is forwarded by routers through the network. Simply go to your command prompt (or terminal or shell prompt depending on your OS).

Type TRACERT followed by a url for a website.

For example, the command “tracert www.compsci.ie” yielded the following path:

```
Tracing route to compsci.ie [193.1.33.39]
over a maximum of 30 hops:

Hop 3 Round Trip Time Delays Some router info, including [IP address]
 4  15 ms  *      11 ms  eth-trunk103.hcore1.dbn.core.eircom.net [83.174.185.50]
 5  10 ms  9 ms   9 ms   lag-201-corea-dbn-hcore1-dbn.corea.dbn.core.eircom.net [83.174.185.12]
 6  10 ms  9 ms   *      lag-61.br1.csg.border.eircom.net [86.43.9.212]
 7  11 ms  10 ms  10 ms  te0-0-0-1-cr2-kp.heanet.net [194.88.240.15]
 8  13 ms  13 ms  *      bundle-ether700-cr2-cwt.nn.heanet.net [87.44.50.2]
 9  13 ms  11 ms  13 ms  tel-1-pw-sr1.services.heanet.net [193.1.236.86]
10  10 ms  11 ms  11 ms  193.1.33.39.pdst.ie [193.1.33.39]

Trace complete.
```

User Datagram Protocol (UDP) is also a transport layer, but it loses reliability for speed. It is used when transmission of all the data is not so important, say for example in video or music streaming.

Voice Over Internet Protocol (VOIP) uses access to the internet to transmit voice messages, bypassing telephone lines. It is also called IP telephony and is one of the most significant developments in telephony since the invention of the telephone itself. Skype is the most well known example, so much so that often the word skype has become synonymous with online video calls.

Our society has become normalised to putting our data on the web. One of the core concepts of the LCCS specification is Data. Many ethical and privacy questions have been raised in recent years around ownership of data. [GDPR](#), a General Data Protection Regulation act, became law across the entire EU on May 25th 2018.

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Stimulate a Debate on how much data, and the kinds of data, governments and giant multi-nationals should be allowed to keep on citizens and consumers.

The model for this activity is explained in [A Summary of Teaching & Facilitation Methodologies](#).

1. Watch a Stimulus Video or read a stimulus piece.

■ [Watch this stimulus on ordering a pizza](#)

Read this piece on rules around patients' medical records.

"The key principle for doctors under Medical Council guidelines is that they must not disclose information about your care or illness to any other person, without your consent. A doctor who breaches confidentiality can be reported to the Medical Council and may face a hearing into his or her conduct. Confidentiality is the cornerstone of medical care. This rule does not apply however, when the information is needed by a court of law."¹⁵

2. Prompt questions to provoke class discussion and elicit initial viewpoints.

- ▶ What were the pros and cons of the Pizza company being able to access the customer's data?
- ▶ Did they have too much access to data, or was their usage of the data at fault?
- ▶ How much data do you think governments or hi-tech companies NEED to retain on citizens? Perhaps a certain amount is required for national security or in the case of online medical companies they could use AI on your data to [prevent future illness, mine your data or suggest treatments](#)?
- ▶ Consider the source of information for the stimulus video. Who are [ACLU](#)?
- ▶ Learn how [Cambridge Analytica used Facebook data](#) to influence the 2016 US Presidential election.
- ▶ [Read the story of how JJ DeAngelo](#) was convicted three decades after his crimes.

LO 1.12

Students should be able to compare the positive and negative impacts of computing on culture and society

¹⁵ Irish Health website <http://www.irishhealth.com/article.html?con=546>

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3. Divide into research groups to explore the topic from key standpoints.

Personal online data is essential to allow governments protect and nurture its citizens and to allow multi-nationals to offer a better service to its consumers.

Themes for different groups:

- ▶ Governments should be allowed unlimited access to citizens' online data.
- ▶ Governments should be allowed no access to citizens' online data.
- ▶ Major institutions, such hi-tech medical or financial firms, should be allowed access to all consumer online data.
- ▶ Major institutions, such hi-tech medical or financial firms, should be allowed no access to consumer online data.
- ▶ When citizens or consumers put their data online, or data is requested from the person, that data is their sole property and should not be consumed by any organisation.
- ▶ When citizens or consumers put their data online, or data is requested from the person, that data ceases to be their sole property and should be allowed to be consumed by organisations that store the data.

4. Choose a teaching / facilitation methodology.

- a. Students first research each topic in research groups of 3.
- b. Use a Jigsaw technique to create groups of 3 comprising one student from 3 different themes. Each person discusses their research within their new group.
- c. Reassemble into original groups.

Each group has up to 5 minutes in the *Hot Seat*

OR

The government could be in the *Hot Seat* followed by an informed citizen or a consumer, followed by a social media multinational. OR

A *Power of Persuasion* technique is used to group students into their preferred category and try to convince other students over to their viewpoint.

OR

A *Think-Pair-Share-Snowball (TPSS)* exercise to broaden out the findings and conclusions of each research group.

LO 1.11

Students should be able to discuss the complex relationship between computing technologies and society including issues of ethics

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Learning Outcomes addressed in this section are listed below.

-
- 1.8** evaluate the costs and benefits of the use of computing technology in automating processes
-
- 1.11** discuss the complex relationship between computing technologies and society including issues of ethics
-
- 1.12** compare the positive and negative impacts of computing on culture and society
-
- 1.13** identify important computing developments that have taken place in the last 100 years and consider emerging trends that could shape future computing technologies
-
- 1.14** explain when and what machine learning and AI algorithms might be used in certain contexts
-
- 1.15** consider the quality of the user experience when interacting with computers and list the principles of universal design, including the role of a user interface and the factors that contribute to its usability
-

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The term **Cloud Computing** is now generally used to mean the delivery of services hosted on the internet. The concept of delivering computing as a service or a utility (like hooking up to the electric grid) is not a new concept. Mainframe computers have existed since modern computing evolved, where end users hook up their terminal to a larger system with greater speed and processing power.

In the 1970's, and before the PC dominated the computing world in the early 1980s, the power of computers was very limited: less processing power than a standard 21st century smart phone. Limited bandwidth and connectivity meant companies could not provide cloud computing on a commercial scale. That all changed in the 1990s as internet bandwidth developed. One of the first companies to capitalise was Amazon. Their Amazon Web Service (AWS), grew out the realisation that their data centres had more computing power than the company could use. So they began to rent their computers as virtual servers to clients who wanted to avail of online storage and computing power. Also the web went from being quite static (web 1.0) to something much more collaborative, responsive, interactive and social (web 2.0). Amongst many innovations, Javascript, one of the prescribed programming languages of the 2017 LCCS specification, has become more and more central to this phenomenon.

What developments have enabled cloud computing and what are some of the key technologies and trends related to Cloud Computing?

Virtualisation

When a company has computing power, or simply an actual computer, to offer as part of a managed service, it will often segment that single resource into a multiple set of resources. Each of these smaller resources, with the appropriate software, can in turn act as a virtual server or virtual storage. Virtualisation is the simulation of a device or a resource. It creates an environment for a user that is independent of physical infrastructure. You can have virtualisation without cloud computing, but you cannot have cloud computing as we know it without virtualisation.

Web 2.0

The web was invented by Tim Berners Lee (link to that section) in 1989. It was quite static in the sense that information was presented using html and users either viewed or downloaded content. It was retrospectively called Web 1.0. As its usage grew and network connectivity improved, people wanted more interaction. Software and Infrastructure as a Service expanded the capability of the web. In the mid 2000s the phrase [Web 2.0](#) was coined to capture this transition to a dynamic world wide web. Take Javascript as an example. Javascript was developed in 1995, more a kind of hacking type of solution to give the browser more choice and responsiveness. In the early 2000s, JS could do more and more through web browsers. And as the web become more and more of a business and social tool, technologies such as AJAX (Asynchronous Javascript and eXtensible markup language) allowed pages to update seamlessly without the need for http requests. Google Maps uses an AJAX engine to allow users work on data in real time in their browser.

📺 [Watch a short \(mashable\) video explaining the cloud and cloud storage.](#)

What is the difference between storage in the cloud and storage in a data centre? Is cloud computing different to cloud storage?

"You don't generate your own electricity. Why generate your own computing?"

Jeff Bezos, CEO Amazon.

LO 1.8, 1.13

[Read a highly concise explanation of Cloud Computing from TechTarget](#)

- ▶ What is the difference between a Public Cloud model and a Hybrid model?
- ▶ The abbreviation "aaS" stands for "as a Service". What does [IaaS, PaaS and SaaS](#) mean, and give some examples.
- ▶ Emerging cloud technologies such as [AI and Machine Learning services](#) are helping to detect fraud, improve weather predictors, etc.

LO 1.13, 1.14

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Cloud Computing makes it possible for dumb to become smart

By the end of 2017 there were more mobile devices connected to the cloud than people living in the world. Smart phones accounted for over half of all internet access, outstripping all other forms of access, such as desktop access.¹⁶ The growth in usage of mobile access is most prevalent in the developing world. The first touchscreen smart phone, the iPhone, was unveiled by Apple in 2007.  [Watch the video](#) and discuss the following questions.

- 1) In the video Steve Jobs claims that Apple have re-invented the phone, and shows a chart as to why the iPhone was unique amongst smartphones. Discuss this chart.
- 2) Examine his claim that the iPhone represented a revolutionary UI and a breakthrough in internet communication.
- 3) Make note of the quote he uses from Alan Kay (who coined the phrase Graphical User Interface (GUI pronounced gooey)) regarding the relationship between software and hardware. Give examples of other hi-tech companies who have followed this trend. (LO 1.12, 1.15)

Why stop at making mobile phones smarter? Imagine if any system which made decisions and had intelligence built into its operation (such as a home heating system) availed of cloud computing and storage? Or if we could intervene early to safeguard a person's health and well-being in their daily lives through data analysers operating in the cloud? The idea is known as the [Internet of Things](#) (IoT). It raises many possibilities and scenarios of an entire world connected to the cloud.



Brain Buster

If the world of things is being rapidly connected, is it inevitable that the human race itself will be permanently connected to the cloud? Or consider the following, is it more desirable to be integrated into the cloud: "Like many transhumanists, Nick (Bostrom) was fond of pointing out the vast disparity in processing power between human tissue and computer hardware. Neurons, for instance, fire at a rate of 200 hertz (or 200 times per second), whereas transistors operate at the level of gigahertz. Signals travel through our central nervous systems at a speed of about 100 metres per second, whereas computer signals travel at the speed of light. The human brain is limited in size to the capacity of the human cranium, where it is technically possible to build computer processors the size of skyscrapers."¹⁷

¹⁶ International Telecommunications Union : <https://www.itu.int/en/ITU-D/Statistics/Pages/default.aspx>

¹⁷ O'Connell (2017) *To Be a Machine*. Granta Publications.

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Stimulate a Debate on Cloud Computing

The strategy below can be used to explore the complex relationship between computing technologies and society. Learning Outcomes [1.11 to 1.18](#) can be covered, depending on the topic being researched and debated. The 4 steps of the classroom strategy to stimulate and facilitate debate are:

1. **Watch a Stimulus Video or read a stimulus piece.**
2. **Prompt questions to provoke class discussion and elicit initial viewpoints.**
3. **Divide into research groups to explore the topic from key standpoints.**
4. **Choose a teaching / facilitation methodology.**

Below are some of the pros and cons of cloud computing designed to act as a stimulus piece for a class debate. The arguments are based on an article on the website [explainthatstuff.com](#). Future trends in cloud computing are also discussed on the same website. Design some prompt questions or use the summary below to help divide the class into research groups to explore the issue from as many standpoints as possible. Facilitation strategies are explained in [A Summary of Teaching & Facilitation Methodologies](#).

CLOUD COMPUTING PROS

- ▶ Lower upfront costs and reduced infrastructure costs.
- ▶ Easy to grow your applications.
- ▶ Scale up or down at short notice, known as elasticity.
- ▶ Only pay for what you use.
- ▶ Everything managed under Service Level Agreements (SLAs).
- ▶ Overall environmental benefit (lower carbon emissions) of many users efficiently sharing large systems.

CLOUD COMPUTING CONS

- ▶ Higher ongoing operating costs. Could cloud systems work out more expensive?
- ▶ Greater dependency on service providers. Can you get problems resolved quickly, even with SLAs?
- ▶ Risk of being locked into proprietary or vendor-recommended systems? How easily can you migrate to another system or service provider if you need to?
- ▶ What happens if your supplier suddenly decides to stop supporting a product or system you've come to depend on?
- ▶ Potential privacy and security risks of putting valuable data on someone else's system in an unknown location?
- ▶ If lots of people migrate to the cloud, where they're no longer free to develop neat and whizzy new things, what does that imply for the future development of the Internet?
- ▶ Dependency on a reliable Internet connection.

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Emerging Trends in the 21st Century

Learning Outcomes addressed in this section are listed below.

-
- 1.11** discuss the complex relationship between computing technologies and society including issues of ethics
-
- 1.12** compare the positive and negative impacts of computing on culture and society
-
- 1.13** identify important computing developments that have taken place in the last 100 years and consider emerging trends that could shape future computing technologies
-

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A Time Capsule Exercise

In the first term of 5th Year, students could use a Think Pair Share mechanism to predict trends and future technology. Their predictions and analysis of future trends could be recorded using the [html demonstration file for CT Challenges in section O of Programming Concepts on the ncca website](#).

Re-visit in 6th year to see if students would review their predictions or if any predictions have already been realised.

■ Watch a video of [10 failed technologies and predictions to see how difficult it is to predict whether a technology will succeed or fade away!](#) Review this ■ [2017 video of top ten emerging technologies](#), including Boston Dynamics amazing robots. See the ■ [background behind the famous exoskeleton video](#) from the Brazil 2014 soccer World Cup, as an inspiring example of future trends in adaptive technology. Since 2012, robotic arms can be programmed by technology that intercepts people's thoughts to perform actions. Watch this ■ [video of a DARPA funded project](#) by a US applied physics department to revolutionise Human Computer Interaction using mind-controlled prosthetic limbs.

9 questions for future trends in the evolution of computers in society

Emerging technological trends are covered throughout the evolution of computers in society over the last 100 years. Some of those trends are greater movement towards cloud computing and cloud services (IaaS, SaaS, etc.) to the implications of the physical limitations reached by Moore's Law and hence a trend towards alternatives such as quantum computing. There will be further emergence of AI and ML technologies in areas such as automated professional, retail and caring services, self-driving automobiles, adaptive technology for a wider variety of human needs, and so forth.

SOME ETHICAL AND CULTURAL QUESTIONS

Further emerging technological trends can be investigated online.

Perhaps just as interesting is how emerging trends are influencing some important ethical and behavioural issues. Using a suitable teaching or facilitation methodology from [A Summary of Teaching & Facilitation Methodologies](#), such as *Stimulate a Debate*, *Think-Pair-Share-Snowball*, or just a simple *Carousel Brainstorming* exercise, examine the following questions through the lens of emerging trends, ethics or the positive and negative impacts on society. ([LO 1.1-1.18](#))

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Some stimulus material and prompt questions are also suggested, and in some cases the teacher and students can brainstorm around their ideas on a question.

0. Wolfram: Is human Intelligence is nothing more than sophisticated computation?

“Normally when we think of computers we imagine constructing machines or programs for specific purposes – to perform tasks we want. And certainly this is what Turing had in mind when he set up Turing machines, or discussed how ‘intelligent machines’ could be built.

Originally motivated by natural science, what I did was to explore the general universe of possible programs – starting with simple programs that one might set up at random, or by enumeration. And what I found – first in the context of cellular automata – was that even extremely simple underlying rules are capable of producing behaviour of in effect arbitrary complexity.

This led me to the general principle – the Principle of Computational Equivalence (Wolfram, 2002) – that implies that beyond some very low threshold, almost any set of rules or programs that one encounters, if it does not have trivial behaviour, it will behave in a way that is computationally as sophisticated as anything else. In other words, it does not take much to be able to do sophisticated computation.”

And the Wolfram concludes:

“But what of abstract intelligence? My conclusion is that there is nothing really to distinguish it from ‘pure computation.’”

Wolfram, S. *Intelligence and the Computational Universe*.

At odds with Wolfram is leading neuroscientist Miguel Nicolelis. You can see one of his [TED talks](#) or look again at his [exoskeleton work](#) that has helped people walk again. He is of the view that “The brain is simply not computable. It cannot be simulated.”¹⁸

1. Jeremy Howard – AI will soon replace doctors. Can caring/people centred professions be replaced by AI?

Jeremy Howard was once head of the data science project company [Kaggle](#). His current AI company is outperforming radiologists in the US. [Watch a snippet \(10:30–19:49\) of a TED talk](#) featuring Howard from 2014. Teachers, Nurses, Doctors, Home Help, etc if they are replaced, what are the implications for health, education, working life, leisure.

18 O’Connell (2017) *To Be a Machine*. Granta Publications (p 56).

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2. Obama - Could the information revolution be the first revolution where the number of jobs destroyed is greater than number of jobs created?

Is there validity in this statement. What are the reasons behind the validity of this statement? Or not! Reference examples. In 2017, [all line judges were replaced with hawkeye](#) in some professional tennis tournaments, with the umpire being the only human judge. Also SMART electricity meters are being installed in Ireland over the coming years. Will a human meter reader be thing of the past? Interestingly, before the invention of the electronic computer, the word computer originally referred to the human who did the number crunching and mathematics.

3. Can we handover responsibility for driving and flying to an algorithm, for killing to war drones, for medical analysis to AI, for care for the elderly to a robot?

The role of AI crossing over to traditionally human responsibilities. [Are drones harmful or helpful, plus Asimov's 3 laws for robots](#). There are real limitations to computers and AI in figuring out the world we inhabit. "Humans are very good at insight and hunches. Computing is very good at doing the same thing over and over again." ¹⁹

4. Are computers and Computing Technology designed for humans and for human interaction?

[Explanations of HCI](#) (Human Computer Interaction) When computing technology is designed for profit or for government use, where is the human on the priority list? Equally, to ensure HCI is about improvements for humans, there must be investment in it or money to be mad in some from?

5. What are the implications for humans if the human mind can be uploaded?

Mark O'Connell's 2017 book [To Be a Machine](#) raises some thoughts on this question... is the mind then a machine ... is it you uploaded?... what will be the substrate for carrying the uploaded mind around? ... can a human brain and its feeling and emotion be reduced to code? The operation of transistors within a computer system share many characteristics with the operation of neurons in the neural networks of our brains. Watch a TED talk on the [art of neural networks](#).

6. If a robot can carry out the same function as a human, is the robot showing signs of intelligence?

If yes, then what is intelligence and what is consciousness... If no then can robots/ machines/ AI ever get to stage where they show intelligence or demonstrate consciousness? ... "at least in principle, I see no reason why it would not lead to an artificial consciousness" Consciousness and the Brain (Dehaene, 2014). [Descartes believed in dualism](#), that the body and mind were two separate things. How would this apply to AI: is its "mind" separate to the processing power, the silicon or the algorithm?

¹⁹ White (2015) *How Computers Work* QUE (10th edition).

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7. What are the positive and negative impacts of military innovations on both society and on technology?

A fully worked example of *Stimulate a Debate* on this question (in the Colossus and ENIAC section of the main resource) allows for this question to be explored in depth. The invention of electronic computers occurred during WWII in response to human computers' inability to decrypt messages with sufficient speed; drones for example can now drop bombs while being remotely piloted and they can also drop emergency goods and supplies in exactly the same way. Which technological innovations did not arise out of military innovations?

8. How much data, and the kinds of data, governments and giant multi-nationals should be allowed to keep on citizens and consumers?

A fully worked example of *Stimulate a Debate* on this question (in the World Wide Web section of the main resource) allows for this question to be explored in depth. Certain kinds of data are vital for governments to function in the interest of its citizens (PPSN, Tax payments, criminal records, etc.). But how much data is too much? Should health records be analysed by government AI to signal who is in danger of diabetes or obesity or dementia in an effort to reduce health care costs and spend taxpayer money more efficiently? Similar arguments apply to both giant hi-tech companies and smaller online companies that need some of your data to operate profitably, and in the consumer's interest. What are the responsibilities and rights of the citizen and consumer in this regard? Should there be a right to take back all of your data with no limitations?

A Summary of Teaching & Facilitation Methodologies

“Leaving Certificate Computer Science is underpinned by collaboration and working with others.”

LCCS specification (2017)

Methodologies previously referenced in this resource are explained in further detail below. There is particular reference to how key skills can be embedded within teaching and learning of Computer Science in general and Computers and society in particular. Each key skill has associated elements and learning outcomes and these are set out in the [Key Skills Framework](#). This summary is not intended to be a comprehensive course in all the elements and learning outcomes of each key skill. Please consult the Key Skills Framework for full details.

We cannot take for granted that students have the necessary skills to be able to engage in genuine dialogue and debate and to work collaboratively and effectively with each other. Skills of listening, summarising, encouraging, criticising ideas (and not people), negotiating differences of opinions, etc. all need to be taught. They also need to be reflected upon through group processing.

Throughout the course students need to be given opportunities to develop the key skills in an integrated way. The use of these types of facilitation methodologies will help to build key skills in senior cycle students.



- ▶ [Brief description of methodologies](#)
- ▶ [Stimulate a Debate Strategy](#)
- ▶ [Further NCCA resources](#)
- ▶ [Helpful tips for groups and discussions](#)

Brief description of methodologies

BRAINSTORMING

Brainstorming is a technique which involves generating a list of ideas in a creative, unstructured manner. The goal of brainstorming is to generate as many ideas as possible in a short period of time. The key tool in brainstorming is “piggybacking,” or using one idea to stimulate other ideas. During the brainstorming process, ALL ideas are recorded, and no idea is disregarded or criticised. After a long list of ideas is generated, these can be prioritised as most/least important, most/least helpful, plus/minus, etc. They can also be ranked 1-5 in order of importance or in the order in which they might be useful in planning a response.

Carousel Brainstorming is another useful technique.

1. The class is arranged into small groups. Each group has a different colour marker.
2. The teacher poses a question on a flip chart, e.g. *Will AI benefit humans in the long run?*
3. The flipchart question is passed from group to group. (To speed up the process you may have a number of pages going around)
4. Each group must add two original suggestions.
5. The flipchart page(s) are displayed for all to see.
6. You can see which group has suggested each idea (by colour) and ask them more about their idea.

THINK-PAIR-SHARE-SNOWBALL (TPSS)

This is an activity to encourage higher-order thinking that involves students thinking individually, then pairing with a partner, then snowballing those ideas with the wider group. The sequence generally begins with the teacher posing an open-ended question, to which there may be a range of responses. Think time or wait time is followed by discussion with a partner. The pair may then pair up to form a square, or share it out to the wider group, and build on each other's ideas. TPSS is also suggested in the lesson resources on the NCCA website for teaching and learning of Programming Concepts.

WALKING DEBATE

This is a well know methodology that can be used and adapted for the Computer Science classroom.

At one end of the room, place an 'I agree' sign on the wall, and on the other end an 'I disagree' sign. Place 'I'm not sure' in the middle of the room and ask the students to stand in this space.

Call out statements and as the students consider each one they move to the position that reflects their opinion. The closer they move towards each sign, the more they agree or disagree. Emphasise that it is okay to stay in the middle and it is also okay to move position according as students hear different views.

In the CS class the teacher can show the complexity of an issue by airing as many different perspectives as possible. Walking debates have been suggested in different sections of the evolution of CS. For example, Can Machines Think? The teacher can also push students to explain and justify their position with evidence by asking questions such as 'Can you give an example of that?' 'What is the evidence to support that view?' 'What have people like Alan Turing or Stephen Wolfram said about this?' 'What will it take for computers to demonstrate they are thinking in such a way to convince humans?' etc.

THE POWER OF PERSUASION

Another strategy to get students thinking is to pose a question which has more than one correct answer: *Why increased automation is a bad idea for society? Or Why the CS revolution will have a very different impact on the developing world than the developed world?* Then get the class to generate four possible answers to a question and vote on their preferred answer.

Count the votes for each answer. Ask the students to sit with their preferred answer groups. Now the job of each group is to persuade others from different answer groups to come over to their group. Give them some time to formulate their campaign strategy. The following questions may be useful to prompt debate:

- ▶ Who is going to speak? What argument will they use? What evidence can they provide to support their argument?
- ▶ Are they going to have a campaign slogan?
- ▶ Which other group will they target?
- ▶ Will they focus on the strengths of their own argument, or on the weakness of the opposition?

During the 'campaign' the teacher acts as chairperson, although this role may also be assigned, especially as the class becomes familiar with the strategy. In the course of the lesson, learners may change sides, or revert to original positions. Leave enough time at the end of the lesson to think about the campaign and the tactics used. A good follow-up homework task for further learning is for students to generate a paragraph or a statement beginning with *I was persuaded because.... or, Answer A won because....*

IN THE HOT SEAT

This is a powerful strategy of putting a learner in a HOT seat, taking the role of a character from fiction or from history. Or of a person from another part of the world or facing a particular challenge.

In the section on the invention of the Web, there is a *Stimulate a Debate* exercise on access to personal data. It suggests that as part of the teaching and facilitation methodology at the end of the exercise, that the HOT seat be taken by the government, then by a major hi-tech multinational, then by a citizen or a consumer. All students can be involved by preparing questions in advance, or by turning the spotlight and putting the whole class in the HOT seat.

PROBLEM BASED LEARNING

Problem based learning offers many benefits. When students are centrally involved in working out what the problem is, and coming to their own understanding of the problem, they will have a deeper understanding of the issue. In problem based learning, it is important that the problem chosen drives the learning rather than providing an example of concepts or theories already taught in class. To be effective problems 'should not be over circumscribed' and instead should be 'ill defined or ill structured so that aspects of the problem are emergent and definable by the learners' (Jonassen 1999).

The characteristics of good problem based learning are

- ▶ multiple criteria for evaluating solutions can be used;
- ▶ uncertainty about which concepts, rules, and principles are necessary for the solution or how they are organized;
- ▶ an absence of prescribed rules or principles for describing or predicting the outcome
- ▶ a necessity for learners to make judgements about the problem, defend their solutions, and express personal opinions or beliefs.

The ALTs described in the specification, the task-based NCCA supports and the PDST manuals all support opportunities for problem-based learning.

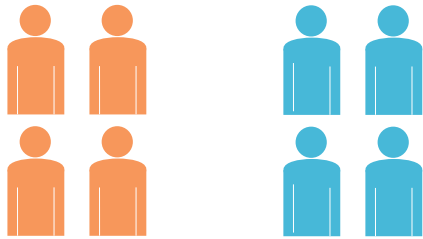
JIGSAW LEARNING TECHNIQUE

Jigsaw groups are a very effective way of organising group work. In this scenario, students are arranged into groups and each group is given a different subtopic related to the one topic. For example, the overarching topic might be *'the role of adaptive technology in all human lives'* (related to LO 1.17) and students might be put in groups and given examples to research (special needs, real-time translation of foreign languages, robotic home help for dependents, etc...) They must become 'expert' on their topic and agree how they are going to teach it to their classmates. When they are ready, the groups are mixed up so that there is now one expert on each subtopic in each group. They take turns 'teaching' their subtopic to each person in the group.

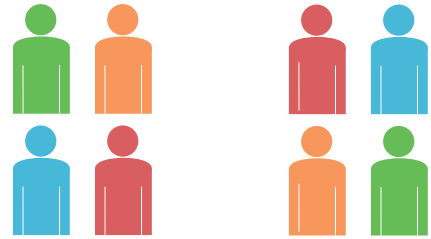
JIGSAW TECHNIQUE



Step 1:



Step 2:



PLACEMATS

Adapted from Barrie Bennett, *Beyond Monet*

Place mat is a form of collaborative learning that combines writing and dialogue to ensure accountability and involvement of all students. It involves groups of students working both alone and together around a single piece of paper to simultaneously come up with lots of alternative ideas.

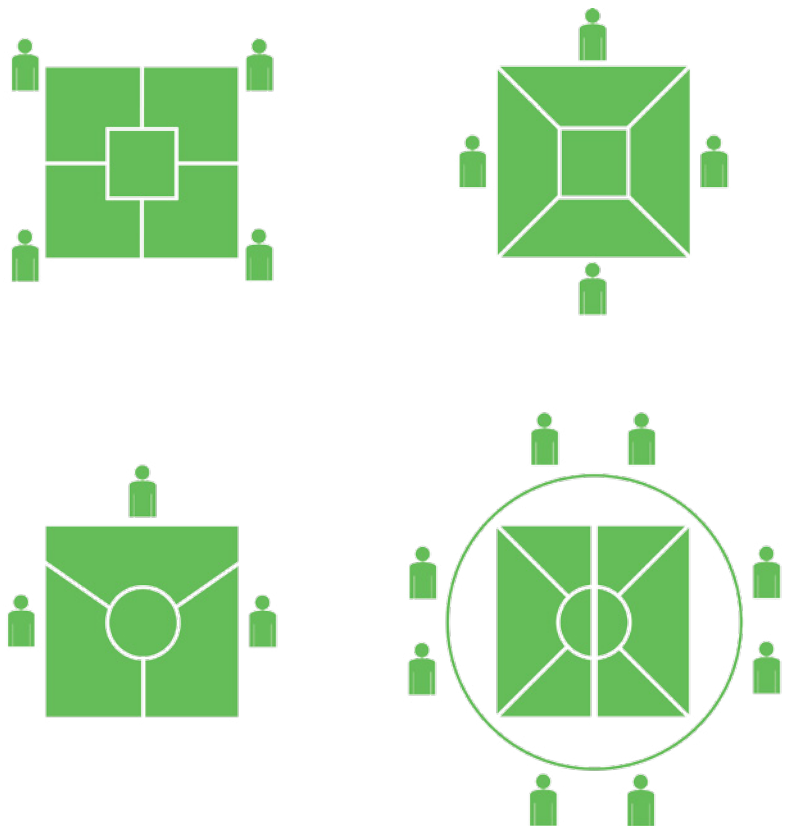
Materials: Flip chart paper is preferable, but not necessary.

The paper is divided up into sections based on the number of member in the group with a central square or circle.

Steps

1. Carefully construct the task or question.
2. Assign students into small groups (3–4 works best)
3. Hand out the task/question with the flip chart page.
4. Students work alone first, using their section of the place mat to record their ideas.
5. Then students share their ideas with the group
6. Then they prioritize the 2–3 big ideas that have emerged from the group and these go on the centre placemat.
7. Sharing then takes place between groups.

Below shows different ways of designing your placemats depending on the number of students in each group. A large poster or flip chart paper works well.



PEER TEACHING / PAIR PROGRAMMING

Peer-to-peer presentation or collaborative paired programming is a methodology that involves students teaching with, and learning from, each other. This is very effective as students must understand a topic in order to teach it to their peers or they can bootstrap their learning from a peer. This type of activity boosts understanding and also builds strong communication and information processing skills as students must think how best to transmit the information.

Stimulate a Debate Strategy

The strategy below can be used to explore the complex relationship between computing technologies and society, and the ethics surrounding the relationship. There are many examples of how to use this strategy throughout this resource. Learning Outcomes [1.11 to 1.18](#) in particular can be achieved, depending on the topic being researched and debated. The 4 steps of the classroom strategy to stimulate and facilitate debates are:

1. Watch a Stimulus Video or read a stimulus piece.
2. Prompt questions to provoke class discussion and elicit initial viewpoints.
3. Divide into research groups to explore the topic from key standpoints.
4. Choose a teaching / facilitation methodology.

1. Watch a Stimulus Video or read a stimulus piece.

It could be background information or provocative arguments around the topic.

2. Prompt questions to provoke class discussion and elicit initial viewpoints.

For example:

- ▶ What will happen to employment – will the growth of computing technology and AI in particular, be a net creator or destroyer of jobs?
- ▶ Will our quality of life improve through cheaper, faster and higher quality health care and greater access to knowledge?
- ▶ Will the rich get richer, and corporations more powerful?
- ▶ Will ordinary citizens be more active and better heard by their government or will government have access to all the data it needs on its people, without consulting them?
- ▶ Will our privacy be assured on this electronic network or will Big Brother end up knowing more about all of us?
- ▶ Should we amend our laws to protect against this new computing technology?
- ▶ How might war and peace be affected? How has the nature of warfare changed?
- ▶ How will human relationships be affected by the accelerated progress of technology and new modes of interpersonal communication?

(These are sample prompt questions based partially on the teachers institute at yale)

3. Divide students into research groups to explore the topic from key standpoints.

These will be typical opposing standpoints in the usual tradition of debating. Students must explore the topic from the assigned standpoint. For example:

- ▶ Military innovations, including wartime inventions, have an overall positive impact on society and on technology.

Equally another research group will investigate:

- ▶ Military innovations, including wartime inventions, have an overall negative impact on society and on technology.

4. Choose a teaching / facilitation methodology.

From the summary of teaching and facilitation strategies, there is a range of strategies such as *Think Pair Share*, *Snowball (TPSS)*, *HOT seat*, *Power of Persuasion*. In addition a *Jigsaw Learning Technique* can be used effectively after research has been done, as well as other classroom strategies that encourage dialogue, debate and feedback.

Further NCCA resources

NCCA RESOURCES FOR SELF-REFLECTION

The [NCCA classroom resources](#) are designed for ePortfolios and for self-reflection. All html resources are designed with minimal code to encourage students to edit the code, modify the resource and include their own programs and reflections. All NCCA resources designed for CS, in the Programming Concepts and ALT sections, are designed as platforms for students to re-use and to develop their own unique resources. Teachers can help students to develop their skills of personal effectiveness in a number of ways. These are described fully in the Building key skills in the Computer Science classroom resource.

NCCA FORMATIVE AND REFLECTIVE BOOKLETS



Giving students opportunities to support each other in their learning through reviewing their own work and their peers' work and giving and receiving feedback.



Encouraging students to record their goals and review their progress, for example, through a journal/blog or the use of student reflection sheets. This helps them to understand their achievements, identify the areas they need to improve upon and plan for future learning.

Download these resources, and more, at this link <https://www.ncca.ie/en/junior-cycle/assessment-and-reporting/focus-on-learning>.

Developing [key skills in the Politics and Society classroom](#) has many strategies similar the ones described in this resource, and many more that are applicable to exploring and discussing ideas in the classroom.

Helpful tips for groups and discussions

ASSIGNING STUDENTS TO GROUPS - TIPS FOR SUCCESS

- ▶ Assign the groups yourself.
 - At times, each group should have a mix of abilities, gender, motivation levels, etc.
 - At times, [generate teams randomly](#). This has the added bonus of de-personalising the selection. Teacher discretion should also be applied here.
- ▶ Start out with small groups (2 or 3) until students become skilful in group work.
- ▶ The shorter the time available, the smaller the learning group should be.
- ▶ Assign each student a job or role but rotate them frequently.
- ▶ Graduate the tasks so that there are some tasks that everyone can do with ease and some more challenging tasks or questions. That way, everyone can contribute something to the group.
- ▶ Make your expectations clear so that students know what you want them to do and how to behave.
- ▶ Agree ground rules.
- ▶ Observe and monitor students working.
- ▶ Teacher's role is to set the task, to keep students focused on the task, support students if they get stuck on the task and give positive feedback.

HELPFUL PHRASES FOR COLLABORATION AND DISCUSSION

- ▶ I think... because (evidence)
- ▶ I agree/disagree because...
- ▶ Let's examine our solutions/ideas we have so far ...
- ▶ Do I understand you correctly, are you saying....?
- ▶ I'm not sure what you mean. Can you say a bit more about that?
- ▶ How can we back-up this idea with evidence?
- ▶ Let's summarise our main ideas so far
- ▶ Let's take turns to make sure that everyone has a chance to speak.
- ▶ Let's check to see if everyone has aired their view or is there another perspective on this?
- ▶ Let's hear from someone who hasn't had a chance to speak yet.
- ▶ I think that's an interesting point but we'd better stick with the question we're working on right now.



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