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The bigger picture

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Unit 06

Chapter 24 – Computing and the environmental impact of technology

It's hard to imagine what life would be like without the Internet, social media, search engines and e-commerce. Global demand for smartphones, tablets and other forms of **computing technology**, including embedded processors, web servers, sensors and hard drives, is growing rapidly year on year.

The manufacture, use and disposal of computing technology has a significant impact on the environment. We are using up resources of non-renewable materials, creating huge piles of potentially harmful **e-waste,** consuming vast quantities of energy and damaging people's health.

Manufacture

RAW MATERIAL EXTRACTION

A number of non-renewable natural resources are used in the manufacture of computer products. They include sand (to make glass for screens), oil (used to make plastics) and various metals used in wiring and circuit boards. Some of the metals used, such as silver, gold, copper and palladium, are precious and in short supply.

PRODUCTION

Computing technology involves extracting raw materials and manufacturing components in factories, often thousands of miles away. This process uses non-renewable fossil fuels, contributing to global warming. Semiconductors are used in computing technology, consuming a significant amount of water, leading to water shortages and environmental pollution. The manufacture of a computer and monitor requires ten times the amount of fossil fuels, chemicals, and water. Exposure to hazardous materials in computing technology can cause physical and neurological damage, and chemical emissions and wastewater put people at risk. The EU Restriction of Hazardous Substances Directive restricts these materials, forcing manufacturers to replace them with safer alternatives.

MATERIAL	EXAMPLES OF USE
Cadmium	A metal used in the manufacture of rechargeable batteries, printer inks and toners.
Lead	A metal used in the manufacture of circuit boards and cable sheathing.
Mercury	A metal used in the manufacture of LCD screens.
Hexavalent chromium	A chemical compound used to make casings.
Polychlorinated biphenyls (PCBs)	Toxic compounds added to plastics, circuit boards and connectors to make them more fire retardant.
Polybrominated diphenylethers	

Usage

The manufacturing process consumes less energy than the daily operation of mobile phones, computers, and networks. However, the energy consumption depends on the task and software used. High-end applications, complex calculations, and video games consume a lot of power. Cloud computing and data centres are major energy users, using large amounts of electricity to power and cool equipment. Energy efficiency measures and renewable energy can reduce the **carbon footprint** of data centers, as seen with Facebook's large data center in northern Sweden.

Disposal

The growing e-waste poses a significant environmental threat, with the UN's StEP Initiative estimating it will weigh eleven of the great Egyptian pyramids. Despite efforts to recycle e-waste, large amounts are sent overseas to developing countries, leading to environmental and public health issues. Unrecycled e-waste contains dangerous materials, which can leak into the ground, contaminate water supplies, and pollute the air. Recovering valuable metals from old computing technology is a priority for locals, but removing equipment without protective clothing and specialist training is dangerous.

Preserving the environment

Things are not all bad. Computing technology can help to fight climate change, provide disaster warnings, protect endangered species and habitats, and
reduce energy consumption.

CLIMATE CHANGE

NASA is analysing satellite data and measuring sea surface temperatures to learn more about how and why sea levels are rising.
Networks of wireless sensor probes are used to gather information about glaciers. The probes are placed under the surface of the ice and measure temperature, pressure, stress, weather and sub-glacial movement. A base station collects the data from them. The system is helping scientists to understand more about the speed at which glaciers are melting.

EARLY WARNING

Tsunami early warning systems use sensor networks to detect approaching tsunamis and a communications infrastructure to issue timely warnings so that coastal areas at risk can be evacuated.

CONSERVATION

Information from GPS and satellites is being used to track Malaysian
elephants. The results are analysed by computer to help improve conservation strategies and assess the effectiveness of the Malaysian Government's elephant conservation programme.
Miniature transponders fitted to bees allow scientists to study the effects of disease and pesticides.

ENERGY

Engineers at Manchester Metropolitan University in the UK are working on a project to make buildings more energy efficient. Sensors in each room monitor light levels, temperature, how many people are present and electricity consumption. Real-time analysis of the room data enables automatic adjustment of electricity usage.

Chapter 25 – Privacy

Now that you know about the damaging environmental impact that computing technology has, does it make you have second thoughts about swapping your smartphone for the latest model? Is your concern for the environment more important than your 'need' for a new phone? If so, you are making an ethical decision. **Ethics** relate to what is right and wrong and govern a person's behaviour.

Computing technology confers a wide range of social and economic benefits, but it also creates challenging ethical issues. Privacy and security are two of them. While most people would agree that computing technology has

helped to create a much more open society, some would argue that it comes at too high a cost. The amount of personally identifiable information that is gathered, stored and analysed represents a massive invasion of **privacy**.

Personal data

Every time you post an update on social media, sign up for an online account, use a web-based email service or a search engine you are adding to a store of **personal data** that is held about you This includes information about where you live, what you look like, who your friends are, your likes and dislikes, your bank account details, products you're interested in buying, the places you visit.

Weak security could result in personal information falling into the wrong hands. This makes people vulnerable to phishing attacks, scams, **identity theft** and fraud.

BIG DATA

Data analysts are able to learn more and more about us and gain insights into our behaviour by analysing huge volumes of personal data gathered from various sources.
Analysis of so-called 'big data' can benefit society. For example, by helping to identify adverse side effects of drugs that might otherwise go unnoticed, optimising energy use in cities and providing insights into the spread of disease.

SURVEILLANCE

Have you any idea how often you've been watched on CCTV today? Could a drone have been hovering overhead taking aerial photographs of you on your walk to school? If you've driven anywhere by car, travelled by public transport or been in a shop, the chances are you've been recorded by some form of **surveillance technology.**

Some people believe that use of surveillance technology goes too far. In 2013 Edward Snowden, a so-called **'whistle-blower'**, raised awareness of the extent to which governments worldwide are now monitoring and spying on their citizens.

LOCATION-BASED SERVICES

With the help of **location-based services** and Wi-Fi, people can share their current location, arrange to meet up with friends nearby, check in to a venue, find their way to a particular location and much more. A disadvantage is that location-based services also allow other people to track your movements, find out where you live and what you are doing. This can be dangerous and represents a huge invasion of privacy.

PRIVACY-ENHANCING TOOLS

Privacy-enhancing tools, while not 100 per cent effective, do give some protection against privacy invasion. This table lists some of the most popular of these tools.

TOOL	PURPOSE
Encryption	Prevents unauthorised people from reading your data.
Cookie cleaners, anti-spyware and ad blockers	Software that detects and removes cookies, spyware and adware installed on your computer.
Identity management service	A trusted third party holds evidence of your identity and issues you with an identifier that enables you to conduct transactions with other parties without revealing any personal information about yourself.
Password manager	Stores all your website login information in an encrypted password database with a master password, which is the only one you have to remember.

Chapter 26 – Digital inclusion

Digital inclusion is about providing everyone with affordable access to computing technology and the skills to use it. The gap between those who are 'technology-empowered' and those who are 'technology-excluded' is known as the **digital divide**. There is a digital divide between industrialised and developing countries and also between people who live in the same country.

IMPACT	There are many reasons why technology exclusion is not a good idea.

TOOL	PURPOSE
Information and services	The Internet is becoming the default option for accessing information, public services and entertainment.
Employment	Having poor digital literacy skills makes it harder to find a job and limits employment opportunities. Individuals might only have access to poorly paid work with little prospect of progression.
Democracy	The Internet gives people a voice and lets them express their views to a worldwide audience. This is particularly important where citizens have limited freedom of expression.
Economic growth	Businesses that are able to exploit computing technology to the full have a competitive advantage over those that can't.
Saving money	Paying bills and shopping online often saves consumers money and gives them better protection.
Social isolation	Having access to the Internet helps people to keep in touch with friends and relatives.

Towards digital inclusion

There are many initiatives to promote digital inclusion, such as:

- A subsidy programme for low-income households has been started in Colombia by the government. It includes subsidies for fixed Internet access. Also, in partnership with the private sector, schools in remote areas have been connected via satellite.

- The government of India has created an online gateway of public information and on-demand services, such as national identity and passport services, employment as well as tax and pension information and services. This is to enhance the relevance of Internet content for its citizens.

- Kenya has established a digital learning programme to drive primary education to enhance digital skills and improve the quality of education.

- The government of Thailand have established more than 20 rural Internet centres nationwide. The centres strengthen ICT skills among students, youth and local communities and help to promote social and economic development in some of the most remote areas of the country.

Chapter 27 – Professionalism

Computer scientists write software to make computers do new things or accomplish tasks more efficiently, create mobile apps, design and build embedded systems, devise security policies, invent new products and much more besides.

Some work for big multinational computing companies, such as Microsoft and Apple. Others for small start-ups; some are self-employed, some are employed in the IT departments of organisations such as hospitals, universities and companies.

Wherever they work they are expected to behave ethically and demonstrate professionalism.
Most countries have ethical guidance for computer professionals. The British Computer Society (BCS) is the Chartered Institute for IT.

The BCS Code of Conduct sets out the professional standards its members are expected to uphold. Among many other matters, it specifies that computer scientists should always respect the wellbeing, privacy and security of the environment and people, never stop learning and gaining skills and professional knowledge. For a full list of the code of conduct of the BCS please visit their website.

Chapter 28 – computing and the legal impact of technology

Intellectual property (IP

Intellectual property (IP) - not to be confused with an IP address - is a unique creative product of a human mind. A piece of software, a computer game, a design for a new processor, a digital image, a piece of music and a literary work are all examples of IP. Each of them was created by somebody, is unique and has a commercial value.

COPYRIGHT AND PATENTS

There is legislation in some parts of the world that makes it illegal to copy, modify or distribute intellectual property without permission. However, there are a multitude of peer-to-peer networks, torrent sharing websites and forums on the Internet that allow people to download copyrighted software without paying for it.

A **patent** offers more protection than copyright. It protects the idea or design of an invention, rather than just a particular form of it. In order to get a patent you have to be able to demonstrate that what you have invented is distinct from anything else that already exists. A patent holder has the exclusive right for 20 years to make, use and sell their invention.

Licensing

Every piece of software, even if it is free, has a licence. Even though the user purchases a piece of software, the licence states that they don't actually own it. The licence allows the buyer to use the software subject to the licence terms, but the manufacturer retains ownership. Before you can install the software, you have to agree to the terms of its licence. These specify:
■how many copies of the software you are allowed to use
■whether you can install the software on more than one computer
■what type of organisation can use the software - some licences are for charities, students or home users only

■how long the software can be used for - perpetual software licences last forever, but some licence agreements expire unless you renew them.

If a computer scientist wants to permit other people to use their code without charge, they can use an open-source licence to specify what restrictions (if any) there are. For example, in the UK a **Creative Commons** licence provides a way for the creator of a piece of music, a photograph or other form of intellectual property - including software - to allow other people to use it providing they abide by the conditions specified in the licence.

Open – source and proprietary software

Open-source software is freely available on the Internet. Anyone is permitted to edit the code and pass it on to others, providing they don't charge a fee. The advantages and disadvantages of open-source software are shown in this table.

SUBJECT VOCABULARY

open-source software software that is free to edit and redistribute
proprietary software software that belongs to an individual or a company. Its licence specifies that users are not allowed to modify the source code and places restrictions on its use

ADVANTAGES	DISADVANTAGES
It is free to use	It might not be particularly user friendly and might look unprofessional
It can be modified	There might be little or no technical support available
It can be used to demonstrate programming concepts	Criminals may be able to identify and exploit vulnerabilities in the code

Proprietary software is the opposite of open source - it is closed source. This means its source code is protected and users are not allowed to modify it.
On the plus side, proprietary software is extensively tested prior to release. This means any bugs that do appear are quickly fixed and there is plenty of user support. The disadvantage is that if the software doesn't exactly do what you want it to, you're not allowed to change it.

Cybersecurity

As you learnt in Unit 5, hacking represents a serious security threat. Many countries around the world including those in Europe and the GCC, as well as Australia and Singapore, have Computer Misuse Acts. These laws make it illegal for anyone to gain access to computer systems without permission, with higher penalties for deleting data or using information for further illegal purposes such as fraud and data theft.

Chapter 29 – Current and emerging trends

Artificial intelligence (AI) covers a range of ideas and technologies. It can mean different things to different people,

In other words, these are machines that solve cognitive problems commonly associated with human intelligence, such as learning, problem solving and pattern recognition.

The core challenges of artificial intelligence include programming computers for certain traits, such as:
■knowledge
■reasoning
■problem solving
■perception
■learning
■planning
■ability to manipulate and move objects.

ARTIFICIAL INTELLIGENCE IN USE TODAY

There are many uses in medicine such as:

- Digital consultations - apps to make a patient diagnosis based on the patient's medical history and knowledge. Users report their symptoms into the app, which uses speech recognition to compare against a database of illnesses. It then offers a recommended action, taking into account the user's medical history.

- Analysing test results - the computer is trained using millions of scans with their confirmed diagnosis. The computer can then spot medical markers far more accurately than a human.

- Health monitoring - wearable health trackers monitor heart rate and activity levels. They can send alerts to the user to get more exercise. It can share this information to doctors and AI systems for additional feedback.

There are also many uses in everyday life:

- Whenever Amazon® recommends a book to you, or Netflix® suggests a film or TV show, those recommendations are based on algorithms that examine what you've bought or watched in the past. The algorithms learn from those purchases, using them to suggest other things you might enjoy. Artificial intelligence lies behind those algorithms.

- Virtual assistants such as Siri® and Cortana® find the information and return the answers to your device, or they control other apps to achieve what you have commanded. Cortana can predict your needs by learning from information gathered and the way you use it.

- When flying an Airbus, the pilot only spends about 3 to 4 minutes manually flying the plane. The planes use a combination of motion sensors and GPS to track their position in flight. The software can even land commercial aircraft.

- Financial companies often use artificial intelligence to monitor transaction requests since algorithms process information so quickly. They spot patterns in your transactions and alert users to suspicious activity.

DNA computing

DNA (deoxyribonucleic acid) is the material that stores the genetic material of all organisms in their chromosomes. In every human cell, there are 46 chromosomes that contain all of the information to 'make' a person and allow them to function within their environment.

Millions of years ago, evolution created a perfect data system, capable of storing huge amounts of data. This has the ability to replicate itself but also has a mechanism to process the stored data to make the chemicals essential for life.

Because of its microscopic size and data storage capabilities, DNA has become a research area for computer scientists. DNA computers would have many advantages over silicon-based ones, such as:

■there will always be a supply of DNA (as long as there are cellular organisms)

■the large supply of DNA makes it a cheap resource

■DNA biochips can be made cleanly, unlike the toxic materials used to make traditional microprocessors

■DNA computers are many times smaller than today's computers.

Its use for computation was first demonstrated in 1994 to solve the problem of finding the shortest route between seven cities, going through each city only once. Strands of DNA were made to represent the seven cities. The strands were mixed in a test tube and they combined together to represent all of the possible routes.

Nanotechnology

Nanotechnology is the manipulation of matter with a size of from 1 to 100 nanometre (nm). One nanometre is 1 millionth (109) of a metre. Therefore, nanotechnology is the manipulation of matter on an atomic and molecular scale.

Nanotechnology is quickly becoming an interdisciplinary field as biologists, chemists, physicists and engineers are all involved in the study of substances at the nanoscale.

Nanotechnology is being used in a variety of areas:

- Self-cleaning glass - nanoparticles are included in the glass. UV (ultraviolet) radiation in light causes them to break down and loosen organic molecules, such as dirt, on the glass.

- Clothing - coating fabrics with zinc oxide nanoparticles gives them better protection from UV light.

- Scratch-resistant coatings - adding aluminium silicate nanoparticles
- to polymer coatings makes the coatings more effective. It increases resistance to chipping and scratches.

- Medicine - anti-cancer drugs that could harm normal tissue can be attached to nanoparticles. They can be delivered directly to the tumour using white blood cells

Quantum computing

Quantum computers are based on **quantum mechanics**. This is the branch of physics which describes the behaviour of the very small, where **subatomic particles**, such as photons or quarks, can exist as both particles and waves. One of the principles of quantum mechanics is the idea of **superposition**. This is the idea that an object can have all possible states, until its state has been measured.

Today's classical computers use bits. As you have learnt in Unit 3, a bit can be set at either 1 or 0. Quantum computers use **qubits**. They are essentially subatomic particles, such as electrons or photons. To generate qubits, IBM and Google researchers use **superconducting circuits** cooled to temperatures colder than deep space.

SUBJECT VOCABULARY

quantum mechanics a theory that explains the nature and behaviour of matter and energy on the atomic and subatomic level

subatomic particle a unit of matter below the size of an atom, including the elementary particles such as quarks that all atoms are made up of

superposition the ability of a quantum system to be in multiple states at the same time until it is measured

qubit a quantum bit, the counterpart in quantum computing to the binary digit or bit of classical computing

superconducting circuits electrical circuits that have zero electrical resistance

Another principle of quantum mechanics can also be used in quantum computers. This is **entanglement**. This means that each of a pair of qubits exist in a single quantum state, and they can influence each other. Changing the state of one of the qubits will immediately change the state of the other. This can happen over huge distances.

Revision questions

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3).
Viza Health Centre is located in the North East of England.

(a) The health centre uses artificial intelligence to provide a symptom-checking
service for its patients.
Patients log on to the website and input their symptoms.

(i) Describe how artificial intelligence could identify what is wrong with them. (2)

(ii) Give one reason why a patient may not want to use this online service. (1)

4).
(d) Santiago wants to find and fix network vulnerabilities before the reputation of the
company suffers.
Discuss the methods he can use.
You should consider:
- ethical hacking
- commercial analysis tools
- review of network and user policies. (6)

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5).
(e) Carlo wants to reduce the environmental impact of his smartphone.

(i) Give one way Carlo could reduce energy consumption. (1)

(ii) Explain one way, other than reducing energy consumption, that Carlo could reduce the environmental impact of his smartphone. (2)

6).
(d) Akiko wants to know how the software she writes can be protected.
Discuss how the software can be protected from illegal copying and/or illegal distribution.
You should consider:

- intellectual property
- Licensing.

7). Discuss the impact of computing technology on the environment. (6)

8). Airtest produces exhaust emissions testing software. A programmer discovers that there is a bug in the software that produces inaccurate results under particular circumstances.
Discuss what course of action the programmer should take and explain why. (4)

9). Assess the extent to which the patent system is a barrier to technological innovation. (4)

10). State two uses of artificial intelligence in the modern world. (2)

11). Discuss the legal and ethical implications of the following situations.

a). Users changing their devices (such as smartphones, tablets and computers) many times. (3)

b). Peer-to-peer file-sharing websites which allow users to distribute commercial audio, images and video to other users across networks including the Internet. (3)

c). A student noticed that the teacher kept a copy of the password for past examination papers on a sticky note attached to his computer. The student used it to log in as the teacher to take a look. (3)

12). Some people have poorer access to computer science technology than others. List two reasons why this is the case. (2)

13). Discuss the positive and negative effects of computer science technology on the environment. (6)

14). Some copyright holders grant Creative Commons licences to users of their works. Provide two reasons why a content creator might consider using a Creative Commons licence to make their work available to others. (2)

15). Tic Toc manufactures smartwatches. It uses proprietary software to develop apps for the watch.

a). What is meant by proprietary software? (1)

b). Explain one advantage to Tic Toc of using proprietary software rather than open-source software to develop apps. (2)

16). State two advantages of DNA computing over silicon computers. (2)

17).
(a) Explain **one** reason why files should be backed up regularly. (2)

(b) Consent must be obtained before organisations can use personal data.
Give **two** pieces of information that organisations must tell people when requesting consent to use their personal data. (2)

18).
(d) Inclusion is an ethical concern.

A school has decided to allow students to bring their own digital device to use in class.

Assess the impact of the school's decision on its ability to be inclusive. (4)

19).
A company recycles digital devices. It uses computers and networks in its business.

(a) The company stores details of its business such as recycling statistics on a server.

Users do not all have the same access to files stored on the server.

Explain the type of access to the statistics file a student on work experience at the company should be given. (2)

(b) Identify the term that refers to software that is out of date and vulnerable to cyberattack.

- A Unaudited
- B Untested
- C Unstructured
- D Unpatched (1)

(c) Explain two ways in which the improper disposal of digital devices could be harmful to human health. (4)