# WJEC AS DIGITAL TECHNOLOGY

## A Complete Course Guide for Theory

*Unit 1: Innovation in Digital Technology*

Covers the full WJEC AS Level Digital Technology specification for Unit 1: Innovation in Digital Technology

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*Definitions are reproduced word-for-word from my own notes, cross-referenced against the WJEC specification.*
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# Introduction

A-Level Digital Technology is (as of the production of this document) still a very new course based on an ever-changing industry. I was disappointed when I realised how few resources there are to support students taking the A-Level. Sure, there are plenty of resources on the Internet that give thorough explanations of the concepts mentioned in the specification, but none of those are specific to the exam. That is what led me to produce this document, specifically tailored to the WJEC A-Level.

All definitions in this document will be in blue, with particularly important parts of the definition being in **bold**. Definitions provided in this document have either been taken directly from WJEC resources or have been slightly modified for improvement of accuracy. I recommend you try to remember definitions word for word - you can use an SRS-based flashcard algorithm (such as with Anki) to help you remember it all.

*If you do intend to use flashcards*, I really recommend you physically type up the definitions into your cards rather than copying and pasting it or using AI to produce a deck. Typing the words yourself gives you a moment to actually understand what you're reading/ typing and plants a seed in your brain for when you actually encounter the card while revising. It's better to clarify anything you don't understand before you need to revise the card rather than after.

*Disclaimer: This document was produced solely by an undergraduate student and an AI assistant, so there may very well be overlooked errors. Feel free to report mistakes to **contact@aiyanhussain.com***

## Notes on the Exam itself

The exam is 2 hours long, which – as with any other exam – will fly by.

Since the exam is taken on a computer, **your ability to type fast is your strongest weapon.** Chances are if you're taking this subject, you're probably into computers anyway, so you might already have decent typing speed. You should start typing right away and let your fingers move autonomously while your mind processes the question. There's no time to waste!

The questions asked in the exams aren't exactly orthodox: you can get questions worth 7 marks with strangely specific mark schemes, or very general 10 markers. The structure you want to take differs depending on the question. You don't need a specific explanation for a 'Describe' question, and you only need to list examples for an 'Identify' question. A good general structure may look like this:

**Main Point → Example → Explanation → Impact**

Example:
Explain **one** ethical constraint with smart devices in the built environment. [4]
"An ethical constraint with smart devices in the built environment can be privacy concerns with people being observed in public *(Main Point).* For example, including public surveillance cameras that are able to identify and store information about people passively, without them realising *(Example).* This means that people, despite potentially being aware that there are cameras, may not necessarily know what kind of data is being captured about them, which can raise privacy concerns for the general public *(Explanation).* This can cause controversy for the organisations using the cameras and handling the data, and may result in a negative perception of the use of smart devices in the built environment."

**Always link the answer back to the question,** even if it seems obnoxious. See what I did in the very last sentence? I basically name-dropped the question word-for-word. It has to be tailored to the question, or else the examiner might think it's not specific enough and mark you down.
Remember, there's nothing to lose with writing a little extra. They can't take marks from you, they can only give marks to you.

# 2.1.1 Connected digital systems and smart devices

## How digital systems connect

These days, devices can connect in all sorts of ways. Most people are familiar with Wi-Fi and Bluetooth as everyday terms, but a real network is built from several distinct pieces of hardware, each with a specific job to do. For your exam, you need to be able to name each component and, crucially, explain what makes it different from the others — examiners love asking you to compare a hub with a switch, or a gateway with a bridge.

### The components of a network

You need to know and be able to differentiate between the following pieces of network hardware:

- Hubs
- Switches
- Routers / Wireless Routers
- Gateways
- Bridges
- Wireless Access Points
- Network Interface Cards (NICs)

> A hub **copies all packets of data to all devices on the network**; only the device that requires the data will recognise and receive it.
>
> A switch **analyses each packet of data and sends it to the computer to which it was intended**.
>
> A router **stores the addresses of computers on the network and transfers data between devices**. It usually connects at least 2 different networks.
>
> A gateway **joins two networks that use different base protocols together** (e.g. LAN to WAN).
>
> A bridge **joins two networks that use the same base protocols together** (e.g. LAN to LAN).
>
> A wireless access point is a device that **allows other Wi-Fi devices to wirelessly connect to a network** (e.g. via a router).
>
> A network interface card (NIC) **allows devices to access a network**. A wireless NIC **allows devices to access a network wirelessly**.

It is easy to muddle hubs and switches up, since both sit in the middle of a small network passing data around — but the exam will expect you to know the difference precisely. A hub is the 'dumb' option: it can tell that something is physically plugged in, but it has no idea what that something is, so it just blasts every packet to every port and lets the devices sort out which packets are actually theirs. A switch is smarter — it can identify the specific devices connected to it and keeps a record of their MAC addresses, so it only sends each packet to the port it is actually meant for. This makes switches far more efficient on busier networks, which is why almost all modern wired networks use switches rather than hubs.

### How data gets from A to B

When you send data to a device on a different network (for example, loading a website hosted on a server elsewhere in the world), it does not go directly there. Instead:

- The sending computer passes the data to a hub or switch, which forwards it on to a router (or the computer may be connected straight to a router).
- The router examines the destination IP address and sends the data on towards the router responsible for that address.
- Any other routers along the way that are not responsible for that IP address will simply reject the data and pass it on.
- Eventually, the router responsible for the destination network receives the data and delivers it to the correct device.

### Protocols and standards

A protocol is simply an agreed set of rules that lets different devices understand each other, in the same way that two people need to agree on a shared language before they can hold a conversation. You should be able to explain how each of the following functions, at least at a broad level.

> Ethernet is a wired (cable connection) protocol, technically known as **IEEE 802.3**. It typically uses twisted copper cable or fibre optic wiring, and operates at the Physical and Data Link layers of the OSI model.
>
> Wi-Fi is a generic name for standard protocols based on the **802.11** family, used for **wireless connectivity on LANs and internet access**. Like Bluetooth, it uses radio frequency technologies to connect devices wirelessly.
>
> Bluetooth is a short-range wireless technology standard, used for **exchanging data between fixed and mobile devices over short distances**. Bluetooth devices broadcast signals to allow other Bluetooth devices to connect (this is called *pairing*), and data is then exchanged.

Common everyday uses of Bluetooth include hands-free systems in cars, smartwatches connected to a phone, and audio streaming to speakers or headphones. Its typical range is around 10 metres for a normal device (Bluetooth Class 1 devices can reach up to 100 metres), which is far shorter than Wi-Fi — and its transfer rates are slower too. That trade-off is deliberate: Bluetooth is designed for short-range, low-power connections between personal devices, not for connecting a whole house to the internet.

> TCP (Transmission Control Protocol) **establishes reliable connections** before transmitting data packets.
>
> IP (Internet Protocol) is a means of **addressing and routing** data packets across a network.

TCP and IP are so often used together that they are usually referred to as a single suite, **TCP/IP**. Broadly speaking, IP is responsible for getting a packet to the correct address, while TCP is responsible for making sure the packets that arrive actually make sense as a whole — in the right order, with nothing missing.

Finally, you should be aware of the generations of cellular network technology, since these are the protocols mobile devices use to connect over long distances (a WAN, rather than a LAN):

- 2G (GSM) – around 50Kbps, enough for SMS text messages and MMS picture messages.
- 2.5G (GPRS) – an early upgrade to 2G that introduced basic mobile data.

- 3G – around 2Mbps, allowing internet access and low-quality video calling.
- 4G – around 100Mbps, fast enough to stream films and music at high quality.
- 5G – around 20Gbps, a superfast connection that supports demanding wireless technologies such as smart factories and driverless cars.

### A closer look: the TCP/IP model

The specification only asks you to explain how TCP/IP *functions*, but it genuinely helps to see the bigger picture of how it is organised. TCP/IP is often described as a five-layer model, where each layer has a specific job and hands data down to the layer below it:

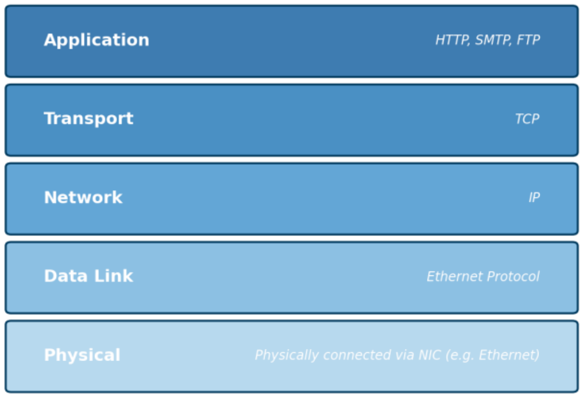


*Figure 2: the five layers of the TCP/IP model.*

### Transmission media

Once you know which protocols are being used, the next question is what the data is actually physically travelling across. The specification identifies three broad categories of transmission media, each with very different capacities.

> Wired transmission media uses **twisted copper cables** (also known as Ethernet cables) or **fibre optic wiring** to physically transmit data.

Copper Ethernet cabling comes in several standard categories, each supporting different speeds:

| Cable | Maximum speed | Frequency |
|---|---|---|
| Cat5 | Up to 100Mbps | 100MHz |
| Cat5e | Up to 1Gbps | 100MHz |
| Cat6 | Up to 1Gbps | 250MHz |
| Cat6a | Up to 10Gbps | 500MHz |
| Cat7 | Up to 10Gbps | 600MHz |

*The five common speed classes of twisted copper cabling.*

> Fibre optic transmissions use **optical fibres that transmit data through light particles (photons) bouncing through the cables**.

There are two common ways fibre optic infrastructure is delivered to a building:

> Fibre to the Cabinet (FTTC) provides fibre-optic connections to a **networking cabinet**, which is then connected to the premises via **twisted copper cabling** (Fibre Optic > Network Cabinet > Copper Cable > Premises).
>
> Fibre to the Premises (FTTP) provides a **direct connection to the physical premises** (Fibre Optic > Premises).

FTTP is generally the better option of the two: it offers faster speeds, more stable connections and a lower carbon footprint than FTTC, since the data does not have to switch to slower copper cabling for the final stretch.

Finally, wireless transmission covers several distinct technologies, each suited to different situations:

> Radio is a form of **electromagnetic waves** used to wirelessly transmit data.

Microwaves have a **higher frequency than radio waves**, and are used in Wi-Fi technology to create WLANs, as well as in WWANs via 2G–3G cellular networks.

> Satellite communication transmits data to **an orbiting satellite**, which **amplifies the signal back** to Earth to the intended receiver. This allows for transmission over wide areas, especially remote areas without any communication infrastructure.
>
> Infrared communication uses **infrared waves** to wirelessly transmit data over short ranges. It is often used in TV remote controls, and can create building-to-building transmissions in LAN networks.

### LANs and WANs

Networks may be wired or wireless, and are usually classified by their scale. A Local Area Network (LAN or WLAN if wireless) covers a small, self-contained area — a single building or site, such as a school or an office. A Wide Area Network (WAN) covers a much larger geographical area, connecting multiple LANs together, often across cities, countries or even the whole globe (the Internet itself is the ultimate example of a WAN).

The key practical difference students often forget is speed: because a LAN covers a small physical area with dedicated cabling, it can typically transmit data far faster than a WAN, which relies on shared, longer-distance infrastructure (such as the cellular network generations above) and is more exposed to congestion and distance-related delay.

## The Internet of Things (IoT)

The internet has not stayed still since it was first created — it has moved through distinct phases, each opening up new kinds of use. Understanding these phases helps explain why the 'Internet of Things' is considered the natural next step in that evolution, rather than something that appeared out of nowhere.

### The four phases in the evolution of the Internet

- **Phase 1 – Connectivity:** email, web browsing and searching.
- **Phase 2 – Networked Economy:** Internet shopping and online marketing.
- **Phase 3 – Collaborative Experiences:** social media, video and cloud computing.
- **Phase 4 – The Internet of Everything:** computing devices embedded in everyday objects; connecting people, data and things together.

### Defining the IoT

> The Internet of Things is **physical objects** (or groups of objects) with sensors, processing ability, software, and other technologies that connect and **exchange data with other systems over the Internet**.
>
> A 'thing' in this context is **an entity or physical object that has a unique identifier** and is embedded with sensors, software, and other technologies for the purpose of **connecting and exchanging data with systems over the Internet**.

One detail the specification specifically expects you to know is **why IPv6 matters here**. Every device on the IoT needs its own unique address, but the older IPv4 standard only allows for $2^{32}$ unique addresses — a number that sounds huge until you consider that billions of individual smart devices, sensors and appliances now need one each. IPv6 expands this to $2^{128}$ addresses, which is what actually makes an 'everything is connected' world possible.

### The Internet of Everything (IoE)

> The Internet of Everything is where **everything including people, processes, data and things are all interconnected via the internet**.

The IoE is built on four pillars:

> People: **all the customers who want services, and all the targets of the companies trying to provide them.**
>
> Process: **gathering, analysing and processing data to facilitate interactions between people, things and data.**
>
> Data: **the value assigned to anything, represented in binary.** Data itself isn't useful, but rather the information that the data provides.
>
> Things: **physical objects which collect, analyse and process data, providing user interaction with the Internet** (e.g. mobile phones, smartwatches, tablets).

Within the IoE, three types of interaction take place:

> People to People (P2P): connections made when **information is transferred directly from one person to another**, without the direct involvement of machines (e.g. live video, social networks, text messages).

> Machine to People (M2P): where **information is transferred between a device and a person** to help the person make an informed decision; the action the person then takes forms a feedback loop.
>
> Machine to Machine (M2M): **direct communication between devices**; sensor data is transmitted between devices, and a program helps interpret and make informed decisions, without the direct involvement of people.

## Smart devices in the home, the built environment and manufacturing

> A smart device is **an electronic device that is connected to other devices** on a network (e.g. via Wi-Fi or Bluetooth).

### Smart devices in the home

Common examples include smart TVs, smart speakers, smart thermostats, smart doorbells and smart fridges. Each brings genuine benefits, but also introduces new risks that simply didn't exist with their 'dumb' predecessors.

**Advantages:**

- **Save money:** smart thermostats can save on heating bills by regulating temperature and avoiding boiler overuse.
- **Increased security:** smart doorbells and cameras can help prevent burglaries and notify homeowners of intrusions.
- **Convenience:** being able to remotely control lights, heating and other devices.

**Disadvantages:**

- **Compatibility issues:** different brands of device may not work with each other.
- **Expense:** some smart home devices are very expensive.
- **Hacking risk:** it is possible for cyber criminals to hack home smart devices and take control of them.
- **Privacy:** smart home devices are constantly on, meaning they are able to listen to conversations.

### Smart devices in the built environment

> The built environment is defined as **human-made surroundings that provide a space for human activity** (e.g. neighbourhoods, towns, cities, and their supporting infrastructure).

Typical examples include traffic management systems, parking systems, smart street lighting, and driverless transport.

**Advantages:**

- **Improved transportation:** traffic speeds and congestion are reduced due to improved traffic management systems.
- **Safer communities:** cities and towns have more surveillance, which can reduce crime.
- **Improved environment:** less pollution due to electric vehicles, smart lighting systems, and so on.

**Disadvantages:**

- **Privacy of data:** individuals are tracked more publicly.
- **Cost:** cities and towns must invest significant money in infrastructure to support smart devices.

### Smart devices in manufacturing

> Industry 4.0 refers to the *4th Industrial Revolution*, when **data-driven and automated digital technology was implemented into manufacturing**.

Examples of smart devices used in manufacturing under Industry 4.0 include:

- **Automated robots:** used by companies such as Amazon to move shelves in preparation for delivery. These robots move autonomously, depending on data supplied by customer demand.
- **3D scanning:** used for quality control and adjusting manufacturing procedures in real time.

- **Smart glasses:** assembly line workers can follow step-by-step instructions in their field of view.

**Advantages:** less human error, improved quality control, and improved productivity/efficiency.

**Disadvantages:** expensive hardware, software and expertise; increased vulnerability to cyber-attacks; and job losses due to automation.

### Underlying technologies of smart devices

Whatever the setting, smart devices are built from the same broad categories of underlying technology:

- **Sensors/inputs:** cameras, microphones, GPS receivers, temperature sensors, pressure sensors, proximity sensors.
- **Outputs:** speakers, monitors.
- **Software and communication technology:** Bluetooth, Wi-Fi, operating systems, and apps that allow user interactivity.
- **How the device controls the process:** microprocessors.

**Advantages of this underlying technology:** increased automation, high productivity, cost savings, and instant data access.

**Disadvantages:** less privacy and security, device compatibility issues, increased network complexity, and a technologically dependent way of life.

### Social, legal, ethical, environmental and professional impact

These impacts apply across all three contexts — home, built environment and manufacturing — and are a favourite exam theme, since they connect technical content to the real world.

- **Data privacy:** smart devices have the potential to constantly record sound and video.
- **Legal implications:** companies must ensure that any data collected on individuals is secure and does not breach the terms of GDPR. Law enforcement agencies will use smart device recordings as evidence.
- **Workplace:** companies use smart devices to monitor employee productivity.
- **Environmental impacts:** infrastructure is needed to support these devices, and technologies such as 5G require additional power to run.

## Impacts of the IoT

Finally, it is worth stepping back from individual devices and considering the impact of the Internet of Things as a whole. As with most digital technologies, the picture is mixed — real benefits sit alongside real risks, and a good exam answer will usually be expected to weigh both sides rather than just list them.

**Positive impacts:**

- Effective communication and instantaneous messaging services.
- Increased business interaction, saving vital time.
- More efficient banking, transactions and shopping.
- Access to the latest news from anywhere in the world.
- The ability to run online courses via virtual assistants using the internet.
- Professionals in healthcare, e-commerce and AI can use IoT devices to carry out jobs more easily.

**Negative impacts:**

- Easy access to age-inappropriate content.
- Social media networks have been shown to have a negative impact on mental health.
- It is relatively easy to steal data or hack into IoT devices.
- The internet makes it easy to spread misinformation or harmful content via the IoT.

Notice how many of these impacts recur throughout this whole unit — privacy, security and the risk of misuse turn up again and again whenever a technology increases connectivity. Getting comfortable with this pattern now will make the AI, HCI and social media topics later in this unit much easier to reason through.

# 2.1.2 The development of Artificial Intelligence

AI is one of those topics everyone thinks they understand until they're asked to define it precisely. This section builds that precise understanding from the ground up: what AI actually is, how Machine Learning fits inside it, how robots put AI into a physical body, and what all of this is used for — and does — in the real world.

## Artificial Intelligence (AI)

> Artificial Intelligence is **the simulation of intelligent behaviour by a computer which enables it to make decisions without human intervention**. This covers systems that perform tasks that usually require human intelligence — for example, speech, decision-making and translation between languages.

### Artificial General Intelligence vs Artificial Narrow Intelligence

Not all AI is created equal — and the specification wants you to be able to distinguish between the AI that already exists all around you, and the AI that (for now) only exists in theory.

> Artificial Narrow Intelligence (ANI) is AI that **focuses on a specific, individual or limited task only and is not self-aware** (e.g. image recognition, predictive text, algorithmic recommendation/personalisation).
>
> Artificial General Intelligence (AGI) is where **an AI system can match or surpass that of human intelligence** and has not been fully realised. An AGI system can learn, generalise and apply knowledge, and should pass the Turing test.

A few characteristics worth keeping distinct in your head:

| Artificial Narrow Intelligence (ANI) | Artificial General Intelligence (AGI) |
| --- | --- |
| Focused on a specific, limited task. | Not fully realised — some developers doubt it is even possible. |
| Associates questions with a specific dataset in order to fulfil tasks. | Can handle a wide range of cognitive tasks. |
| Not self-aware; the AI cannot think for itself. | Able to learn, generalise and apply knowledge to questions asked. |
| Already exists everywhere: chatbots, predictive text, hyper-personalisation. | Would consistently pass the Turing test, and possess common sense, creativity and expressed emotion. |

### Testing for human-level AGI

Because AGI has never actually been achieved, researchers have proposed thought experiments — tests a machine would need to pass to be considered genuinely as intelligent as a human. You need to be able to describe how each of the following works.

> The Turing test was **proposed by Alan Turing in 1950**. A human interrogator must distinguish between a computer and a human respondent, based on their responses to the interrogator's questions, within a certain timeframe. **The computer is considered an AI if the interrogator cannot distinguish between the human and computer respondent.**

> The Wozniak/Goertzel Coffee Test, originally stated by Steve Wozniak and later refined by Ben Goertzel, requires the computer to **identify all ingredients, accurate quantities, and perform the correct brewing process**. If the computer can produce a human-level cup of coffee, it is considered an AI.
>
> Nilsson's Employment Test, proposed by Nils John Nilsson, gives the computer **a number of human jobs to be able to fulfil**. If the computer can fulfil the tasks at the same or better quality than a human, it is considered an AI; AGI is evaluated on the basis of measuring what fraction of these jobs can be acceptably fulfilled.
>
> The Goertzel Robot College Student Test, proposed by Ben Goertzel, gives a computer **equal resources to human students in order to achieve the same degree**. If the computer can achieve the degree, it is considered an AI.

### The enablers of AI

AI is not new as an idea — but it is only in the last couple of decades that it has become genuinely useful and widespread. Three enablers explain why:

> Moore's Law: the number of transistors in a dense integrated circuit **doubles about every 2 years and the cost halves**. From 1965 (when Gordon Moore first discussed this) the rate doubled every year until 1975, and has since doubled roughly annually — though since 2010, improvements to semiconductors have slowed down.
>
> Huang's Law: developments in graphics processing units (GPUs) in computing and engineering grow **at a far faster pace than central processing units (CPUs)**, at a rate of more than double every 2 years.
>
> Cloud computing is using a **network of remote servers hosted on the Internet** to store, manage, and process data. The development of fast internet connectivity, along with huge data sets easily distributed and accessed from any point in the connected world, enables large data-based Artificial Intelligence.

### Ethical constraints and social implications

AI systems learn from data — and if that data reflects existing human bias, the AI will reproduce and can even amplify it. This matters most where the data concerns **gender, ethnicity or language**, since a biased model trained on biased data can end up systematically disadvantaging particular groups (for example, a recruitment AI trained on historic hiring data might learn to favour candidates who resemble those hired in the past).

## Machine Learning (ML)

> Machine Learning is a specific sub-set of Artificial Intelligence **that trains machines how to learn by automating the process of creating analytical models**.

The key thing that separates a Machine Learning algorithm from a traditional, hand-written algorithm is where its instructions come from. A traditional algorithm follows a fixed, pre-set sequence of steps written by a programmer. A Machine Learning algorithm is not given explicit step-by-step instructions in advance — instead, it learns its own 'instructions' from training data, and its results are probabilities rather than certainties. This is why a spam filter, for instance, doesn't tell you a message is definitely spam — it tells you it is, say, 97% likely to be spam.

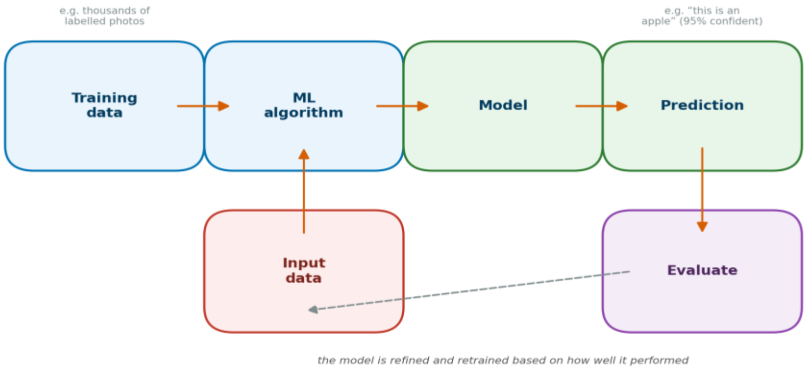


*Figure 3: the basic training pipeline shared by most Machine Learning systems.*

### Supervised, semi-supervised and unsupervised learning

The specification expects you to be able to explain the difference between these three approaches. A useful way to keep them straight is to imagine you want a system to correctly identify a photo of an apple.

> Supervised learning: a data-set is fed to the AI model (e.g. images of apples). A different data-set is fed with a specific association to the original data-set (e.g. telling the model that those images are of apples). Finally, a brand new set similar to the original is fed, so **the system now knows to associate those data-sets together** (e.g. the model can now identify what apples look like).
>
> Unsupervised learning: a data-set is fed to the AI model (e.g. pictures of many different types of fruit). The machine analyses it, trying to **identify any patterns** (e.g. colour, size, shape). The machine **categorises the data based on those identified patterns** (e.g. a category of red fruits, orange fruits, yellow fruits) — those categories will be mainly similar (e.g. one category of mainly apples, another of mainly bananas).
>
> Semi-supervised learning: a data-set is fed to the machine and it is asked to identify something (e.g. providing a data-set of fruit pictures and asking it to identify one). The machine takes data from the data-set and **provides incorrect information** (e.g. selecting an image of an apple and calling it an orange). The machine is **given correct feedback, then selects again, and more feedback is given**. The process continues and the machine learns from the feedback, becoming more accurate over time.

## Robotics

> A robot is a **machine that a computer can programme** that can undertake a complex series of actions automatically. A robot can be guided by an external control device, or the control may be embedded within it. Robots may be constructed to evoke human form, but most robots are task-performing machines, designed with an emphasis on stark functionality, rather than expressive aesthetics.

Robots generally fall into three broad categories: **static** robots (e.g. in manufacturing/car assembly), **virtual** robots or bots (e.g. on social media or in phone calls), and **mobile** robots (e.g. domestic robots such as vacuum cleaners).

### The main components of a contemporary robotic system

- **Central Processing Unit:** the CPU, AKA the 'brain' of the robot, is the component responsible for almost all of the robot's processing via the fetch-decode-execute cycle.
- **Sensors:** used to measure real-life values of quantities sensed (e.g. light, sound, temperature).
- **Actuators:** small motors directly attached to the machine structure to facilitate movement.
- **End-Effectors:** equipment that does the actual work and interacts with the environment for the workplace (e.g. the 'grabbers' of a remote control robot, or the cameras on a drone).
- **Power Supply:** the electrical fuel used to give energy to the system to operate.
- **A Program:** the actual programming logic, sometimes software, that is used to perform functions and tasks.

### Programming robots

Robots can be programmed in two broad ways, online or offline, each with its own methods:

> Teach Pendant Programming (Drive Through): the robot is programmed via a Teach Pendant/Box. The programmer **controls the robot through the process step-by-step at a slow pace**. The robot records the process and is able to reproduce it at a faster, more efficient pace.
>
> Teach by Example (Lead Through): the operator **manually and physically leads the robot through the process**. The robot records the movement, and reproduces it at a faster and more efficient pace.

**Advantages of online programming:**

- Usually quicker.
- Full understanding of programming isn't required.

**Disadvantages of online programming:**

- Must close down the production line when programming.
- The programmer must be in the same place as the robot when programming.

> Offline programming (OLP) is a robot programming method in which the **programming of the robot is created autonomously/independently**. A common example of OLP is Graphical Offline Programming (a form of simulation).

**Advantages of offline programming:**

- The production line can continue while robots are being reprogrammed.
- Robots can be simulated graphically before they are used on the real thing.
- Offline programming is safer for more complex tasks.

**Disadvantages of offline programming:**

- Additional software must be purchased for the offline programming.
- Programming knowledge is required.

## Robots in the real world

Robots are used across many scenarios — the home, education, manufacturing, healthcare and driving among them. As with any technology, they bring both real benefits and real costs.

**Advantages of using robots:**

- Unlike humans, robots can work continuously without breaks and without a loss of quality or speed.
- Robots can produce near-perfect quality work.
- Robots are cost-effective despite the initial expensive purchase.
- Robots can work in dangerous environments (e.g. highly radioactive areas).
- Robots can work much faster than humans.

**Disadvantages of using robots:**

- There are high initial costs due to purchasing and training.
- Robots can cause unemployment in jobs that involve manual labour.
- Robots require skilled staff to be able to operate/program them.

## Concerns, unintended consequences, and safeguards

Beyond the practical trade-offs above, the growth of autonomous robots raises deeper concerns that examiners like to test:

- **Emergency situations:** robots aren't emotionally and intellectually equipped to handle emergencies.
- **Replacement/unemployment:** concerns about mass unemployment arise from the development of robots.
- **Social isolation:** robots may cause humans to work with each other less, causing greater isolation from one another.

> Unintended consequences are **the outcomes of technology that are not part of the intended use and were not planned for**.

Four unintended consequences of robotics you should be aware of:

- **Less patience and willingness to persevere:** people have gotten used to getting immediate answers from search engines, and experts say technology can affect patience.
- **Removal of unskilled jobs:** as robots become more competent, some jobs requiring low-skill labour may be completely automated.
- **Dehumanisation:** the choice of whether or not a human should be used to carry out a task may become harder as robots become more competent.
- **Lack of accountability:** as technology improves, people may disregard good health advice as they believe technology can fix any problems (e.g. prosthetics, retinal implants).

The best-known proposed safeguard against these consequences is a thought experiment rather than real law — **Asimov's Laws**, from science-fiction writer Isaac Asimov, which are nonetheless a useful reference point for how developers might frame ethical constraints on robots:

> First Law: **a robot may not injure a human being or, through inaction, allow a human being to come to harm.**
>
> Second Law: **a robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.**
>
> Third Law: **a robot must protect its own existence, as long as such protection does not conflict with the First or Second Law.**

In practice, real safeguards against the unintended consequences of robots rely on developers **conforming to a legal and ethical framework** — data protection law, health and safety regulation, and industry codes of conduct — rather than the Laws themselves, which were written as fiction rather than legislation.

Finally, the wider social and ethical implications of increased robotics use include: dual use of technology (all technologies can be used and abused), the humanising of the relationship between people and machines, addiction to technology, and the digital divide — unequal access to technology and technological resources worldwide.

## Applications, functions and potential uses of AI systems

### Underpinning technologies of AI

Behind almost every AI application you interact with day to day sits one (or more) of the following underpinning technologies:

> Conditional probability measures the **likelihood of an event considering that another event has occurred** (e.g. the likelihood of coughing on any day may be 5%, but the likelihood of coughing considering you have a cold may be 75%).
>
> A suggestion/recommendation engine is a system that suggests products, services, and information to users based on an analysis of data. **They can derive from factors like user history and similar user behaviour.**
>
> Pattern recognition is the process of **identifying recurring patterns within data via Machine Learning** (training data is used to train pattern recognition systems). Prediction uses recognised patterns to **anticipate future outcomes** (e.g. the likelihood of spam, or the probability of someone clicking a link).
>
> A neural network is a type of machine learning algorithm that **uses a network of interconnected nodes to process data**.

Neural networks rest on four key aspects:

- **Massive models:** models of data with an extensively high number of parameters, and subsequently a large amount of data. The more parameters a model has, the more data it can hold and the more computational power it has.
- **Massive data:** the very large data sets needed to train models with this many parameters.
- **Trial and error:** processes that aim to turn an idea into code, experiment, and evaluate the result, then make changes and repeat the process until a satisfactory outcome is reached.
- **Deep Learning:** a type of Machine Learning that uses multiple layers of artificial neurones to progressively extract higher-level features from the raw input.

### Types of problem AI can solve

> SLAM (Simultaneous Localisation and Mapping) is a computational program associated with **building or updating the map of an object's environment while simultaneously knowing the object's location** within that environment. It is used in autonomous robotics, self-driving cars and drones.
>
> NLP (Natural Language Processing) is one of the sub-fields of computing and relates to **interactions between computers and human language** (e.g. an AI model being given a document to scan through and find certain keywords).
>
> Machine translation is the process of **translating content automatically from one language (source) to another language (target) without any human input** (e.g. entirely translating a letter from English to Welsh).
>
> Anomaly detection (or outlier analysis) is a step in the data mining process that **identifies data points, events and/or observations that deviate from the behaviour of a normal data set** (e.g. identifying fraudulent activity in banking).

> Image recognition is the ability of software to **identify items, places, people, writing and actions in images** (e.g. being able to identify between a cat running and a person playing tennis).

### Common uses of AI

You should be aware that AI is now applied across a huge range of everyday sectors, including:

- Translation engines
- Healthcare
- Cyber security
- Transport
- Entertainment
- Education (detecting plagiarism)
- Voice command (voice to text/smart data)
- Social networking (auto-tagging)
- Shopping (search/recommendation)
- Finance (fraud detection/credit scoring)
- Communication (filtering)

## Impacts of AI

As AI becomes more capable and more widespread, it brings a set of anxieties that go beyond any single application — these are broader, societal-level concerns rather than problems with one particular AI system.

Four recurring concerns about the rapid growth (proliferation) of AI:

- Mass unemployment
- Loss of control over AI
- Ethics of the AI model
- Privacy concerns

In response, safeguarding against AI's unintended consequences — including through **regulation** — is considered essential. The main principles worth remembering are:

- Remembering the social implications of a technology before deploying it.
- Recognising that humans still need jobs.
- Maintaining personal privacy.
- Ensuring people's rights are considered.
- Making sure the value of human life isn't compromised.
- Ensuring decisions made are inclusive.
- Actively avoiding bias.

# 2.1.3 Digital technology development life cycles

No digital product appears fully formed. Every app, website and system you use has gone through a lifecycle — from an early idea, through design and development, to release, and eventually to being replaced by something newer. This topic covers that whole journey: the stages a technology passes through, the approaches developers use to build it, and what happens once it is out in the world and needs replacing or maintaining.

## The stages of the digital technology development life cycle

### The S-curve model

The S-curve model plots the economic benefit of a digital technology against time. As the name suggests, when you plot this out, it forms a distinctive S-shape made up of four stages.

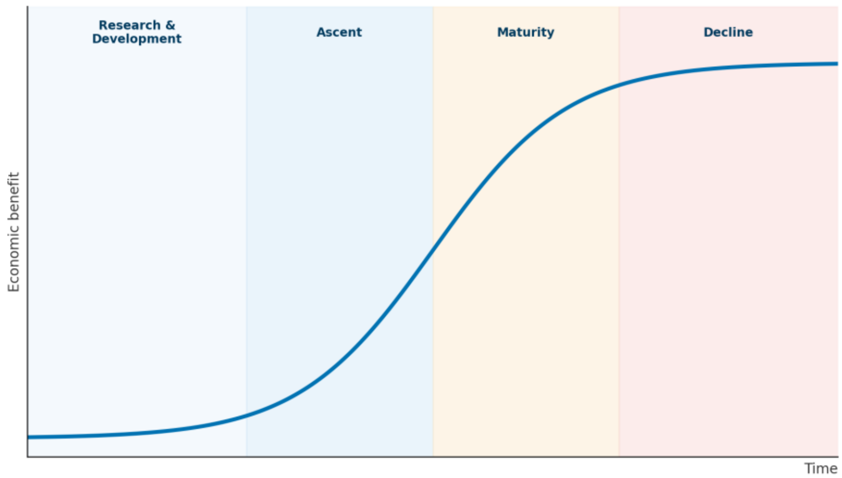


*Figure 4: the S-curve model, showing economic benefit against time.*

> Research and Development: **initial ideas for a digital system are drawn up and the system is created**. Existing digital systems may return to this stage to help solve problems, but the resultant system will be better than the system being replaced.
>
> Ascent: there is **rapid improvement in the main performance of the system** and it starts to become better than the system it replaced. The system is also trying to enter several market segments to gain customer recognition.
>
> Maturity: the digital system or product is **almost completely accepted and approaching its maximum capacity**. Profits are still considerable and minor improvements can still be made, but a forthcoming decline should be anticipated.
>
> Decline: this is when a **new generation of digital system comes into operation**, giving rise to a brand-new S-curve for the new product, and replacing the current product that is in decline. However, the replaced system may find new uses in areas like sports and entertainment.

### The S-curve in terms of economic benefits

Each stage of the S-curve corresponds to a distinct pattern of economic growth for the business behind the technology:

> Initial Slow Growth: **businesses initially experience slow growth as they gradually gain more customers and develop their products.** This occurs during Research & Development.
>
> Rapid Growth: **businesses experience faster growth as customers learn about their products.** This occurs during Ascent.
>
> Late-Stage Growth: **as growth starts to slow down, businesses experience slow economic growth and need to take counteractive measures, such as new products or market shifts.** This happens during Maturity.
>
> Stationary Demand: **businesses' growth or a product's demand remains static or decreases, and the business may choose to adapt with new products.** This happens during Decline.

### Classifications of users who take up new technology

Not every customer adopts a new technology at the same time. Sociologists classify adopters into five groups, and the specification expects you to recognise each one — this is often tested by giving you a scenario and asking which category a described customer belongs to.

- **Innovators (≈2.5%):** 1st to take up new tech. Willing to take risks and try new things.
- **Early Adopters (≈13.5%):** 2nd to take up new tech. They test a new product before recommending it.
- **Early Majority (≈34%):** 3rd to take up new tech. They buy products based on the recommendations of early adopters.
- **Late Majority (≈34%):** 4th to take up new tech. More reluctant to adopt new technologies.
- **Laggards (≈16%):** Last to take up new technology. Easily frustrated by and wary of new technology.

## How digital technologies are designed

Whichever methodology a team ultimately follows (see the next section), the development of a digital technology moves through six broad phases:

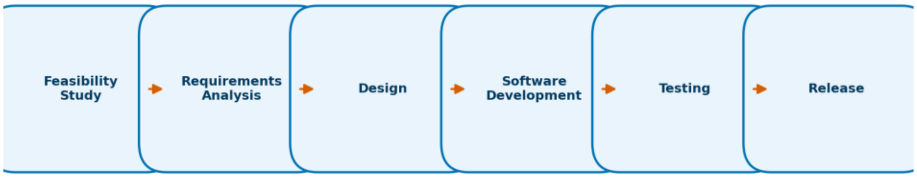


*Figure 5: the phases within the development of digital technologies.*

### Feasibility study

> A feasibility study is **a preliminary investigation in which a proposed project is determined to be viable or not**.

A feasibility study determines whether or not a project is achievable, acts as a preliminary investigation, and — done properly — can save a business a lot of money by catching a doomed project early. It typically examines five types of feasibility:

- Legal Feasibility
- Time Feasibility
- Technical Feasibility
- Economic Feasibility
- Political Feasibility

### Requirements analysis

Once a project is confirmed as viable, the team defines exactly what the system needs to do. Three types of requirement are analysed:

> Functional requirements: **the specific functions or operations that the system must be able to perform in order to be fit for purpose.**
>
> Performance requirements: **the processing demands of the new digital system's computer infrastructure to be able to carry out the task.**
>
> Interface requirements: **requirements for how information in a digital system is presented and controlled by a user.**

### Design

At this stage, the team documents how the system will actually be built, covering four key aspects:

- Hardware & Software choices
- Data Structure design
- Input design
- Output design

> A technical document needs to **explain how the system works and how it is to be maintained in the future.**
>
> A user document explains, in a simple and easy to understand manner, **how to use the software system.**

### Software development

During development itself, four aspects need to be actively managed:

- Version management
- Documentation
- Implementation of standards
- Methodology

### Testing

Testing matters because no software is bug-free, testing verifies usability, it saves money in the long term, and it ensures higher-quality software overall. You should know five forms of testing:

> Alpha testing is when **internal programmers test for bugs or issues in the system's software.**
>
> Beta testing is when **a small group of external users test to give feedback on the software's functionality, and identify any bugs not found in Alpha testing.**
>
> White Box testing is when **testers have full knowledge of the internal code and logic, and is used to identify any parts of code that are not behaving as intended.**
>
> Black Box testing is when **testers don't have any knowledge of the internal code, and tests to see if the software functions and outputs as intended.**
>
> End-User testing is when **the final digital system is given to the intended client and the system is tested against the original requirements.** This is used to determine whether a system is ready for release.

Software is only ready for release once it has passed end-user testing, and can only be signed off as complete once *the client agrees that the software meets their requirements and is fully working*.

### Release

Release brings together two considerations covered in more depth over the following pages: choosing a changeover strategy, and deciding between a gradual roll-out or a full release.

### Roles of individuals within a development team

A development team is made up of several distinct roles, each responsible for a different aspect of the phases above:

> Product Owner: **the person that knows how the final product should look, as they have in-depth knowledge of the project. They also best understand the client's requirements, so are best suited to lead the development team.**
>
> Engineering Manager: **the person responsible for the successful development of the entire lifecycle.** They plan the project, define a scope, implement the plan, monitor progress and mark the end of development. They are in charge of the software engineers.

Software Architect: **they define the essential aspects of the software's internal structure and technical aspects.** Large experience in programming is required, but also leadership skills to help and motivate the software developers.

Software Developers: **the 'building blocks' of the project. They are responsible for solving logical issues found in the project.**

UI Designers **are responsible for designing the user interface — how the software looks.** UX Designers are responsible for creating a good user experience — **how the software behaves.**

Business Analyst: **the person in charge of analysing the client's business needs.**

QA Engineer: **looks at the processes used to develop software and determines whether they are efficient enough or not.**

## Relevant approaches and methodologies

A methodology is the overall strategy a team follows to organise the phases above. Different methodologies suit different kinds of project, and the exam regularly asks you to justify which methodology would suit a given scenario — so pay close attention to when each one works well, and when it doesn't.

### Waterfall

> This approach contains a series of **stages that are arranged in order**, with each stage feeding into the next. No stage of development can begin until the preceding stage has been completed, and each stage ends with a deliverable or handover documents to inform the next stage.

**Advantages:**

- It is simple to understand and suitable for large projects where the requirements are easily understood.

**Disadvantages:**

- It is bad at reacting to changing requirements and is not suitable for projects where requirements may not be fully understood at the start.

### Rapid Application Development (RAD)

> The RAD approach puts **less emphasis on planning and more emphasis on an adaptive design process**. Requirements do not always need to be clear or precise at the start, and prototypes are often used in addition to (or instead of) design specifications — the product is refined repeatedly through trial and error.

**Advantages:**

- The software can be more usable, and developers can focus on business problems rather than technical ones.

**Disadvantages:**

- A lack of emphasis on non-functional requirements.
- Poor design where developers are constantly making minor changes to individual components and ignoring system architecture issues.

### Agile

> An agile approach **values collaboration over processes and tools**, with a strong focus on providing programmers with the tools and resources they need and trusting them to solve the problem as efficiently as possible.

**Advantages:**

- Makes it possible to develop well-written solutions quickly.
- A more flexible alternative to structured development methodologies.

**Disadvantages:**

- Some agile techniques, such as pair programming, are not popular among developers or managers.
- A lack of documentation and specific deadlines can lead to problems with customers who are unfamiliar with the approach.

### Spiral

> This approach is a **risk-driven** software development process model. Based on the unique risk patterns of a given project, the spiral model guides a team to adopt elements of one or more process models — it is often used by large organisations for expensive and complex projects, as it enables constant adjustments to be made.

**Advantages:**

- Additional functionality or changes can be made at a later stage.

**Disadvantages:**

- Risk of not being on time and in budget.

### Big Bang

> Big Bang focuses on **all the possible resources in software development and coding**, with very little or no planning.

**Advantages:**

- Ideal for repetitive or small projects with minimum risks.

**Disadvantages:**

- Very high risk, and can turn out to be very expensive if requirements are misunderstood.

## Changeover

> Changeover: when a digital system is **no longer required or is no longer fit for purpose**, an organisation needs to carefully consider how it goes about implementing a new digital system to replace the old one.

### Parallel changeover

> Old and new systems are **run at the same time for duplication of all tasks**, while the new system is continuously edited to maintain consistency and improve.

**Advantage:**

- If one fails, there is a backup.

**Disadvantage:**

- Duplication of effort, so not something you would want to do for a long time.

### Phased changeover

> Parts of the new system are released **replacing their respective old parts**, eventually replacing the old system as a whole.

**Advantage:**

- Works well with RAD.

**Disadvantage:**

- Requires the old system to work alongside the new system.

### Pilot changeover

> The new system is released to a **self-contained branch** before being finalised and released to the rest.

**Advantage:**

- Only one branch is affected by any problems.

**Disadvantage:**

- Only works if branches are almost identical, e.g. supermarkets or bank branches.

### Direct changeover

> Immediately change to the new system, **completely replacing the previous system with no rollback**.

**Advantage:**

- Works best when there is no previous system, e.g. a brand new mobile app.

**Disadvantage:**

- High risk if it fails.

## Maintenance

> Maintenance is the process of **fixing problems** and **improving the functionality** of a digital system to be fit for purpose.

All digital systems need maintenance eventually — there are two aspects to it (fixing problems, and adding new functionality), and four recognised types.

> Preventative maintenance is when the software is developed in order to **fix potential problems before they occur.**
>
> Corrective maintenance is when **problems and issues arise after release**, so the business must correct them with updates.
>
> Adaptive maintenance is maintaining a digital system to **always meet the dynamically changing requirements.**
>
> Perfective maintenance is the idea that **all digital systems can be further improved by optimisation** (e.g. optimising software to run as efficiently as possible on a range of devices).

### Maintenance across data, software and hardware

The specification expects you to be able to give examples of maintenance for each of these three areas.

**Data maintenance** is the process of optimising data designs and database features. Examples include:

- Data cleansing: finding and fixing inaccurate data.
- Data quality control: making sure data is updated, useful and fully accurate.
- Deduplication: removing duplicated data from your system.
- Purging data: removing unusable or low-quality data from your system.

**Advantage:**

- Optimises data designs and database features.

**Disadvantage:**

- Time-consuming to design.

**Software maintenance** is undertaken for reasons including:

- Reducing the costs of adding new features and services to systems.
- Maturing processes to save time.
- Preparing for any issues that may arise.
- Ensuring continuity of the project.
- Increasing the security of data.

It is typically achieved through optimisation, error correction, deletion of discarded features, and enhancement of existing features.

**Advantage:**

- Reduces the costs of adding new features and services.

**Disadvantage:**

- The initial outlay is expensive.

**Hardware maintenance** covers physical repair of hardware, hardware optimisation, contract maintenance and per-incident repair, for reasons including:

- Decreasing equipment downtime.
- Conserving assets.
- Creating cost savings.
- Improving safety.
- Increasing equipment efficiency.
- Improving reliability.

**Advantage:**

- Decreases equipment downtime.

**Disadvantage:**

- Specialist staff are required.

Finally, remember that maintenance is rarely free: the company producing the technology will typically fix problems for a period of time after release, either through a rolling maintenance contract or an upfront payment, and will otherwise charge for individual fixes on an ad hoc basis. Even where an update looks ‘free’ to the customer, that cost is usually rolled into the original price.

# 2.1.4 User-centred design, user experience and human-computer interaction

A brilliantly coded system that nobody can figure out how to use is, in practical terms, a failure. This topic is about the human side of digital technology: how people and computers actually interact, how designers put the user at the centre of the design process, and how we measure whether a digital product actually gives its users a good experience.

## Human-computer interaction

> Human-computer interaction (HCI) is **the communication between people and computer systems, and how efficient the system is**.

When designing for HCI, four factors need to be considered:

- Needs & wants of the HCI system
- Visual appeal of the HCI system
- Physical limitations and abilities of the users
- Technical characteristics and limitations of the hardware & software

### The User Interface and types of interface

> The User Interface (UI) is **anything a human may interact with to use a digital product or device**.

You should know four broad types of interface, and be able to compare them:

> Graphical User Interfaces (GUIs) present the user with **graphical elements, such as windows, icons, pointers, and menus (WIMP)**, to interact with the computer. This is the most common type of interface.
>
> Command Line Interfaces (CLIs) use **text-based commands to interact with the computer.** This is typically used by advanced computer users, e.g. Linux OS users.
>
> Menu-Driven Interfaces present the user with **a series of menus or options to choose from** in order to interact with the computer.
>
> Natural-Language Interfaces allow users to interact with a computer system **using natural language, such as spoken or written words**, as opposed to specialised commands or syntax. This is the most natural and intuitive type of interface.

You may also come across touch user interfaces (based on the sense of touch/haptics) and voice user interfaces (using speech recognition, which may or may not involve full natural language understanding) — both are variations on the categories above.

### Input methods

A wide range of input methods exist, each suited to different circumstances — the exam likes to test whether you can justify why a particular input method suits a particular use case.

| Input | Typical use | Reason for use |
|---|---|---|

| | | |
|---|---|---|
| Pointer (mouse, trackball, light pen) | Graphics creation, FPS games | 2D motion is quickly converted into input. |
| Keyboard | Essays, programming | An efficient and fast way to input text and commands. |
| Touch (touchscreen) | Mobile apps | Allows direct interaction with what is displayed. |
| Movement/gesture (e.g. Wii, Kinect) | Video games | Increases user engagement. |
| Virtual reality headset | Entertainment/gaming, training | Provides a realistic, immersive experience — e.g. surgeons can practise without being in a real emergency. |

## Social and health issues of HCI

Spending time interacting with digital systems is not risk-free. The specification expects you to know the issues associated with five categories of device, and — just as importantly — how each can be mitigated.

### Mobile devices

- Reduced physical activity and/or sleep, potentially leading to obesity.
- Addiction to mobile phones (‘nomophobia’), which can lead to low self-esteem, depression or anxiety.
- Social isolation, which may harm well-being and mental health.
- Accidents caused by distraction while using a mobile device.
- Exposure to blue light, which can suppress melatonin and interrupt a user's circadian clock (sleep cycle).

**Mitigations:** cutting back on phone use, swapping phone experiences for real-life ones, keeping a regulated sleep routine, applying blue light filters, and seeking help from a mental health professional where needed.

### Desktop and laptop devices

- Repetitive Strain Injury (RSI) from repeated hand/arm movement.
- Back, neck or shoulder pain.
- Dry eyes or eye strain, and headaches.
- Laptops tend to cause more problems than desktops, since the keyboard and screen position can't be adjusted independently.

**Mitigations:** taking regular breaks, looking away from the screen for 20 seconds every 20 minutes, improving the environment (e.g. better lighting), and using ergonomically designed technology.

### Peripheral devices

- RSI from using a mouse or keyboard.
- Respiratory issues from exposure to printer toner ink.

**Mitigations:** using ergonomic mice or keyboards (with wrist support), and limiting exposure to toner/increasing ventilation around printers.

### Augmented reality and virtual reality devices

- Myopia (short-sightedness).

- Dizziness and nausea (‘VR illusion’, where the eyes focus on objects that appear distant but are actually on a screen centimetres away).
- Headaches.
- Social isolation from spending too much time in a virtual rather than real world.
- Physical danger from being unaware of real surroundings, e.g. tripping.

**Mitigations:** increasing exposure time slowly, using a seated or ‘comfort’ mode, taking frequent breaks, ensuring the headset is properly fitted, and using anti-nausea technology such as a wristband.

**Software applications**

- Inaccurate information provided by an app (e.g. a health diagnosis or symptom-checker app giving the wrong advice) can lead users to make poor decisions or cause unnecessary worry.

**Mitigation:** verifying information by cross-checking multiple sources.

## User-Centred Design (UCD)

> User-Centred Design (UCD) is **an iterative process where designers focus on the users and their needs in each phase of the design process**. The purpose of UCD is to design the product to the needs of the user, rather than the user having to adapt to the product.

### The five principles of UCD

- A clear understanding of user and task requirements — gained through research such as interviews, surveys and user observation.
- Incorporation of user feedback — using feedback from testing to iterate and improve the design.
- Active involvement of the user to evaluate the design of a product — e.g. through usability testing, design workshops and user feedback.
- Integrating UCD with other development activities — applying it throughout the whole project, not only at the design phase.
- An iterative design process — the design is developed and refined across multiple cycles, evolving over time based on feedback and testing.

### The four phases of the UCD process

Because UCD is iterative, these four phases form a repeating cycle rather than a one-off sequence:

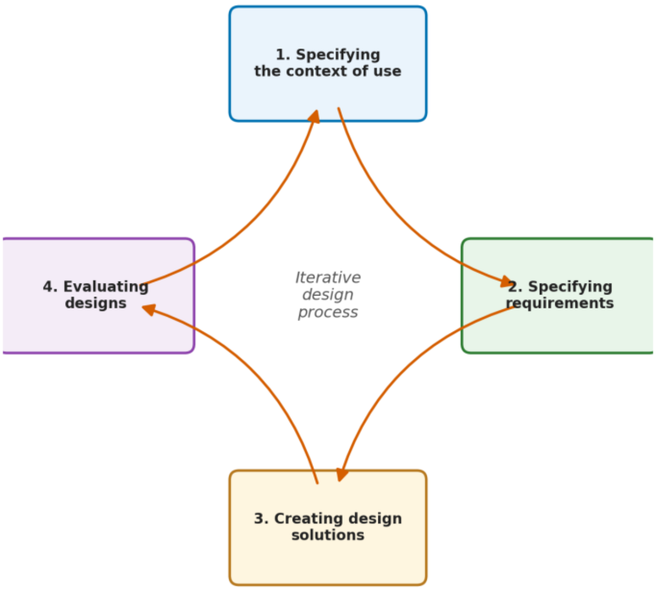


*Figure 6: the four-phase iterative UCD cycle.*

**Phase 1 — Specifying the context of use:** identifying product users, use circumstances/situations, the digital medium being used with the system, and the environment in which the system will be used.

**Phase 2 — Specifying requirements:** the digital product's requirements are defined, user expectations are considered depending on budget and time, and — since the process is iterative — requirements may not be final at this stage and will be fine-tuned later.

**Phase 3 — Creating design solutions:** the design team starts to build various product features and assets.

**Phase 4 — Evaluating designs:** evaluations are made to check whether the Phase 2 requirements have been met; further iterations and requirements are then determined, and the four stages repeat as the design improves.

### How requirements are noted and refined

> Ethnographic study: **observing people in their natural environment in order to understand their perspective** (e.g. designers living and working with users temporarily, observation, interviews, surveys).
>
> Continual feedback: **the idea that there is a cycle of designing, then receiving feedback, then refining.** This is part of the iterative design process.
>
> Contextual enquiry involves **observations and interviews in the user's own specific environment**, and is specifically user-centred to a certain task.
>
> Prototype and usability testing is where **a rudimentary working model of a product is used to demonstrate basic functionality** (the prototype).

### Tools used in UCD

> A persona is a **fictional biography of a user that might use the digital product**, including demographics, preferences, attitudes, skills, and other background information.
>
> A scenario is a brief 'story' that **describes how and why the persona would use the product to complete a specific task in a specific context**. Its purpose is to help the design team understand how a user might interact with the product day to day.
>
> A use case is a document that describes **all the steps taken by a user to perform a particular activity or achieve a certain goal** on the system.

A use case is normally broken down into three elements:

- **The Actor:** the user of the system (could also be a persona), e.g. a school student.
- **The System:** the steps taken to reach the end goal, e.g. an online assignment system to submit an essay document to be marked.
- **The Goal:** the successful outcome, e.g. the essay document being successfully submitted to the teacher.

### The main considerations of UCD

> Visibility: **the user knows exactly what the product is for and what they can do with it as soon as they start to engage with it** (e.g. immediately being able to understand that a mobile app is used for banking).
>
> Accessibility: **the general user-friendliness for everyone that uses the digital product** (e.g. some users may prefer keyboard shortcuts, others may prefer menus).
>
> Legibility: **text should be easy to read for all** (e.g. using appropriate fonts).

Four general rules of legibility are worth remembering: ornamental ('fancy') fonts and all-capitals text are difficult to read; italics and bold are useful when used correctly; text that is too large or too small is hard to read; and good contrast between text and background increases legibility.

> Language: **how information is communicated from the system to the users** — those using the product should be able to easily understand the language used.

## Digital User Experience (DUX)

> Digital User Experience is **the overall experience of a person using a digital product or service**, such as a website or mobile app.

### The five aspects of DUX

> Design: **the practice of designing digital products with the user's needs and preferences in mind.** This involves understanding a user's goals and motives, then designing the product to help achieve those goals.
>
> Navigability: **the ease with which a user can move around and find what they are looking for** (e.g. having well-designed menus, appropriately named buttons).
>
> Performance: **the speed and reliability of a digital product** (e.g. loading times, response time, features working every time).
>
> Efficiency: **the ability of a digital product to help the user achieve their goals in the most effective way possible, by minimising input and maximising output.** Users often have limited time and attention, so need to complete tasks as quickly as possible.
>
> Cross-platform compatibility: **the ability of a digital product to be used on multiple platforms and devices** (e.g. accessing cloud storage from an iPhone, a Samsung tablet and a Windows PC; or accessing a game save from a PS5, a Switch and a mobile phone).

### DUX beyond the screen: wearables, VR and AR

> Wearables allow users to **access information and technology without having to carry a separate device**, such as a smartphone or laptop. The DUX of a wearable largely determines its success.

- Fitness trackers: personalised fitness goals produced by AI algorithms; haptic feedback (e.g. vibration when a step goal is reached); usually worn on the wrist for convenience.
- Smartwatches: a good GUI with easy navigability and clear, large buttons; haptic feedback, e.g. vibration when messages are received.
- Smart clothing: sensors built into shoes, gloves and tops; a very haptic user experience since there is no traditional user interface — e.g. a shirt with sensors that monitor heart rate and vital signs.
- Implanted devices: not yet mainstream, but placed inside the body or under the skin to track diseases or health conditions — e.g. a diabetic using an arm implant to monitor blood sugar via a phone app.

> VR and AR are used to **provide immersive and realistically simulated DUXs**, such as training simulations, virtual tours, or gaming.

The specification wants you to be able to give examples of VR/AR use across sectors:

- **Education/training:** realistic training, immersive-experience learning, virtual field trips in schools.
- **Healthcare:** training doctors, immersive cognitive behavioural therapy, augmented telehealth/telemedicine.
- **Business:** letting customers see how furniture would look in their home (AR); virtual test drives for car manufacturers (VR); training employees (VR).
- **Architecture:** seeing how a proposed building would look on-site, or at different times of day (AR); virtually remodelling homes (VR).
- **Military:** practising procedures in a realistically simulated environment; real-time information and guidance during missions.

- **Entertainment:** immersive games and experiences; visiting places of interest such as museums or concerts.

### Elements used when evaluating DUX

Beyond the five aspects above, evaluating DUX properly draws on seven elements:

> Aesthetics of design: **the visual appearance of the digital product or service** (e.g. layout, colour scheme, typography, imagery).
>
> Information architecture: **the practice of organising and structuring information in a way that makes it easy for users to find and understand** — this includes navigation, labelling and hierarchy.

Accessibility in this context covers six aspects: the ease of use and overall usability of the interface; the ability of users with disabilities to access and use the product; overall user satisfaction; the level of support for assistive technology (e.g. screen readers, speech-to-text); accessibility features such as on-screen help and plain language; and conformance to standards/guidelines such as the Web Content Accessibility Guidelines and the UN Convention on the Rights of Persons with Disabilities.

Human-computer interaction, in the context of DUX, is considered in three ways:

> Anthropomorphic approaches: **including elements that would be natural to human users** (e.g. natural language).
>
> Cognitive approaches: **the product aligns to the way a user thinks, and their mental abilities** (e.g. algorithmic suggestions, website layouts following user expectations, undo buttons to allow for human mistakes).
>
> Empirical approaches: **the experience is designed with real-world studies and data in mind** (e.g. collecting feedback in the beta stage, then acting on it for the final release).
>
> Ergonomics is **designing products to fit humans, ensuring that they are comfortable and easy to use, without causing strain or injury to the user** (e.g. natural movements like swiping and tapping).
>
> Utility refers to **the usefulness and relevance of the digital product or service to the user**, and how well it meets the user's needs and goals.

Performance, as before, covers the speed and reliability of the product.

### Metrics used to test and evaluate DUX

> Task success rate: **percentage of tasks or goals that are successfully completed** by users of a digital product.
>
> Task completion time: **time it takes for users to complete a specific task or goal** using a digital product.
>
> Retention rate: **percentage of users that continue to use a product** after a measurable and comparable period of time.
>
> Conversion rate: **percentage of users who are persuaded to take a specific action** or complete a specific goal — used, for example, in e-commerce to measure the effectiveness of a website's persuasion to make a purchase or fill in a form.

Error rate: **percentage of errors when carrying out a particular task** (e.g. an error rate of 5% for online purchases means 5% of attempts include an error, though the purchase can still ultimately be successful).

Satisfaction: **overall measure of how well the digital product meets the needs and expectations of the user.**

Heuristic evaluation: **using common experience, intuition and trial and error to evaluate DUX** (e.g. a group of expert web designers using their experience and knowledge of good websites to evaluate the DUX).

## 2.1.5 Functions, purposes and uses of social media by individuals and organisations

Social media is probably the part of this unit you already have the most first-hand experience of — but the exam isn't interested in your opinion of your favourite app. It wants you to be able to categorise different platforms, name their functions precisely, and reason carefully about the legal, ethical and professional consequences of how individuals and organisations actually use them.

### Types of social media

> Social media is a computer-based technology that facilitates **the sharing of ideas, thoughts, and information through virtual networks and communities**. This can be via web-based software or applications on devices.

The specification identifies ten distinct types of social media, each with a different purpose and different features:

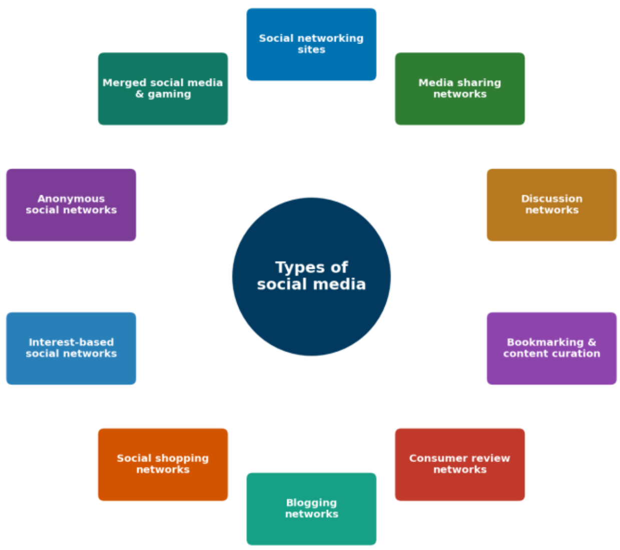


*Figure 7: the ten types of social media identified by the specification.*

> Social networking sites are **online platforms used by people to build social networks or similar social relationships with other people**. They enable users to connect with people and brands online (e.g. Facebook, LinkedIn, Twitter).

Social networking sites typically operate on desktop, laptop and mobile devices; let people connect across the world; allow users to create a profile and invite others as friends; support sharing and discussion with people of similar interests; enable social community groups; allow sharing of experiences, ideas, activities and interests within a network; and support chat and/or videoconferencing.

> Media sharing networks enable users to **search, store and share their multimedia files over a social media network** — e.g. images, videos and music (TikTok, Instagram, YouTube, Flickr). Businesses use these networks to increase their audience, carry out market research, and increase platform engagement.

Discussion networks are social media platforms that **focus on discussing news, information and opinions** (Discord, Reddit, Quora). Businesses use them to involve their target market in communications, create topics for discussion, and upload content for marketing.

Bookmarking is the process of **tagging a web page with a browser-based tool so that you can revisit it**; content curation is the process of **gathering information relevant to a particular topic or area of interest**, usually to add value by selecting, organising and looking after items in a collection (Pinterest, Flipboard). Used effectively, these networks build brand awareness, increase engagement and generate website traffic.

Consumer review networks are **online platforms that enable consumers to provide public opinions and scores for products, companies or services** (Tripadvisor, Yelp, Trustpilot). They give businesses free third-party feedback, help build long-term customer loyalty, and can improve search engine optimisation and reputation.

Blogging networks **allow businesses to publish content for their target audience**, building engagement and familiarity (Tumblr, LiveJournal, Medium). They require constant content creation, and so demand more ongoing work than other platforms.

Social shopping networks involve **the buying and selling of products online within a social media platform** (Instagram Shop, Facebook Shop, TikTok Shop), where individuals share, recommend and suggest products or services to one another.

An interest-based social network is **built around common interests, using common threads to bring audience members together** (Goodreads for books, ReverbNation for music, Ravelry for knitting and crocheting). Discussions here are commonly between strangers who will never meet.

Anonymous social networks are where **users under a random pseudonym can anonymously share thoughts openly**, without being judged or bullied (Ask.fm, Whisper).

Merged social media and gaming is the idea of **combining elements of social media and video games together**, to create an immersive and social experience for players (Twitch, Discord).

## Functions of social media

Whatever the type of platform, most social media shares a common set of underlying functions:

> A profile is **a way to show people who you are**, including a short biography, images and anything else representing the individual.
>
> Status/wall posts are ways to **share one's thoughts with friends, family or the public on social media**, giving opportunities to comment and interact based on what is shared.
>
> Uploading media is a way to **keep a log of events, videos, audio, images, texts and other media**. A social media post that includes a photo is 10x more likely to attract attention.

Advantages of uploading media include creating a digital photo album, attracting attention for important messages, and sharing achievements with friends and family. Disadvantages include personal details or location being visible in the background of photos, and posting media potentially leading to real danger (e.g. posting that you're abroad can invite a burglary).

Messaging on social media covers instant messaging, uploading media (photos/videos), group chats, voice messages, video calling, and the ability to block other users.

> Notifications indicate **that something has happened on social media**, often combined with a flag, red dot, sound or haptic feedback, and allow people not to have to constantly check social media for updates.
>
> A newsfeed is **the main system for delivering content to users, tailored to the user's preferences**. Anything can be removed from a newsfeed if a user doesn't want to see it.
>
> Comments & reactions **allow people to build connection with friends and strengthen social media presence** through text, video or audio.

Comments and reactions build connections, start discussions, encourage engagement, and let people share opinions and ideas — but they can also invite trolling, start arguments, attract spam, and discourage people who feel anxious about commenting first.

Sharing and saving/bookmarking allow posts — links, photos, films, TV programmes, music, books and events — to be revisited later, and mean content saved locally can still be accessed even after it is removed from the original platform.

> Privacy & security settings help users indicate **whether or not to give consent to the collection, use and disclosure of personal information** on a social network.
>
> Integration with other social media platforms **provides an opportunity to reach a larger audience**, and as a result a brand will engage and interact with more customers — e.g. connecting Instagram with Facebook to post on both, or using a Google account to log into other apps.

## Purpose and uses of social media

### Individuals

For individuals, social media serves several core purposes:

- A quick and easy way to connect with friends & family.
- A way to share anything you want via statuses, photos and videos.
- An opportunity for those living far away to feel part of an individual's life.
- A good way to network and meet new people.

### Organisations

For organisations, social media serves a different set of purposes:

- Discovering new ideas and trends.
- Connecting with existing and new audiences in deeper ways.
- Attracting people to their work.
- Building, shaping and improving their brand image.

The specification also expects you to be able to discuss **influencer marketing** as a key contemporary use of social media by organisations.

> Influencer marketing is where **brands pay 3rd party influencers to use social media posts in order to promote a product, person, or idea** (e.g. Instagram users with large followings posting about a newly released product).

**Advantages of influencer marketing:**

- Reaches out to more customers.
- Makes the business look popular.
- Posts can be reused multiple times.

**Disadvantages of influencer marketing:**

- Can be expensive to pay influencers.
- The influencer scene is oversaturated.
- Influencers may create misleading posts, which can harm the business.

### Legal, ethical and professional implications

This is where social media content most often crosses over into exam questions on law and ethics. The specification lists a wide range of implications you should be ready to discuss, including (but not limited to):

> Data protection: the **General Data Protection Regulation (GDPR) 2018**, which replaced the Data Protection Act 1998, **lays down rules relating to the protection of people's personal data held by organisations**. Under GDPR, personal data must be: processed lawfully, fairly and transparently; collected for specified, clear and lawful purposes; limited to what is necessary; accurate and kept up to date; kept no longer than necessary; and processed securely.
>
> Libel is a statement that **causes damage to the image of the individual or organisation it relates to**. Such statements can lead to legal proceedings — and importantly, sharing or even just ‘liking’ a libellous post can also be considered a crime against personal honour, not only writing it.

> A troll is an individual who **deliberately tries to incite conflict, hostility or arguments on social media**, often via controversial messages designed to provoke an emotional response and disrupt discussion.

Organisations sometimes deliberately use this dynamic themselves, in a technique called **troll marketing** — where a company posts something controversial on their platforms, often by trolling competitors, the public, or celebrities/public figures.

Deliberate miscommunication and misrepresentation is used by some companies to create **misleading advertisements** on social media to gain a competitive advantage. For example, Skechers claimed their shoes helped people burn calories with each step — technically true, but equally true of any other shoe — and had to settle for $40 million as a result.

Social isolation and bullying are also key concerns: cyberbullying in particular can have serious consequences, including for mental health.

Social media is also increasingly used *as a source of information about an individual* — for example, an employer checking a job applicant's social media profile as part of a hiring decision. This carries real professional risk: refusing an interview based on a protected characteristic visible on a social profile is illegal discrimination, and using information from a social network without consent may be challenged under GDPR.

Finally, consider the *responsibility that comes with a large following* — a public figure with hundreds of millions of followers can communicate with an enormous audience directly and instantly, raising real questions about the responsibility that comes with that reach, and whether it changes their obligations compared to traditional media.

## Impacts of social media use

As with every technology in this unit, social media has a mixed record — genuine benefits sit alongside genuine harms, for both individuals and organisations.

**Positive impacts:**

- Communication and remaining in contact with others.
- Education — discussing educational topics and accessing learning content.
- Business advertisement, allowing organisations to market services to a large audience.
- Access to the latest news from anywhere in the world.
- Highly mobile — accessible from several devices and places.

**Negative impacts:**

- Lack of face-to-face contact, replaced by online interaction that is believed to result in lower-quality relationships.
- Oversharing and digital footprint — information shared publicly can harm future job prospects.
- Excessive use and addiction.
- Fear Of Missing Out (FOMO).
- Cyberbullying, which has had serious consequences including depression and, in the most extreme cases, suicide.
- Harm to self-image.
- Cybercrime, including identity theft, where criminals gather personal information posted about people.
- Privacy issues.
- Fake accounts.
- Phishing.

### Digital footprints

Much of this risk comes down to the digital footprint a person leaves behind — the trail of data created by their online activity, which splits into two types.

> A passive digital footprint is created by data you **unknowingly leave behind** when using the Internet (e.g. completing an online questionnaire, agreeing to cookies, posting on social media, subscribing to a newsletter).
>
> An active digital footprint is created when you **knowingly submit information** on the Internet (e.g. applications using geolocation, companies using your likes and comments for personalised algorithms, or being tagged in a photo on a social network).

Understanding this distinction is genuinely useful beyond the exam: most of the legal and ethical concerns above — GDPR, libel, professional consequences of hiring decisions — ultimately trace back to exactly what kind of footprint a person has left, and whether they realised they were leaving it at all.