GCE AS/A LEVEL

WJEC GCE AS/A Level in

DIGITAL TECHNOLOGY

APPROVED BY QUALIFICATIONS WALES

GUIDANCE FOR TEACHING

Teaching from 2022

For AS award from 2023
For A level award from 2024

WJEC GCE DIGITAL TECHNOLOGY

UNIT 1 GUIDANCE FOR TEACHING

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AIMS OF THE GUIDANCE FOR TEACHING

The principal aim of the Guidance for Teaching is to support teachers in the delivery of the new **WJEC GCE Digital Technology** specification and to offer guidance on the requirements of the qualification and the assessment process. The Guidance for Teaching is **not intended as a comprehensive reference**, but as support for professional teachers to develop stimulating and exciting courses tailored to the needs and skills of their own students in their particular institutions.

AIMS OF THE UNIT GUIDES

The principal aim of the Unit Guides is to support teaching and learning and act as a companion to the Specification. Each Unit Guide will offer detailed explanation of key points in the Specification and aim to explain complex areas of subject content. An overview of the whole course can be found in the Delivery Guide.

1. INTRODUCTION

The **WJEC GCE in Digital Technology** qualification, approved by Qualifications Wales for first teaching from September 2022 is available to:

- all schools and colleges in Wales
- subject to local agreement, it is also available to centres outside Wales, for example in the crown dependencies of the Isle of Man and the Channel Islands, and in British overseas territories, and to British forces schools overseas. It is not available to other overseas centres or in England or Northern Ireland.

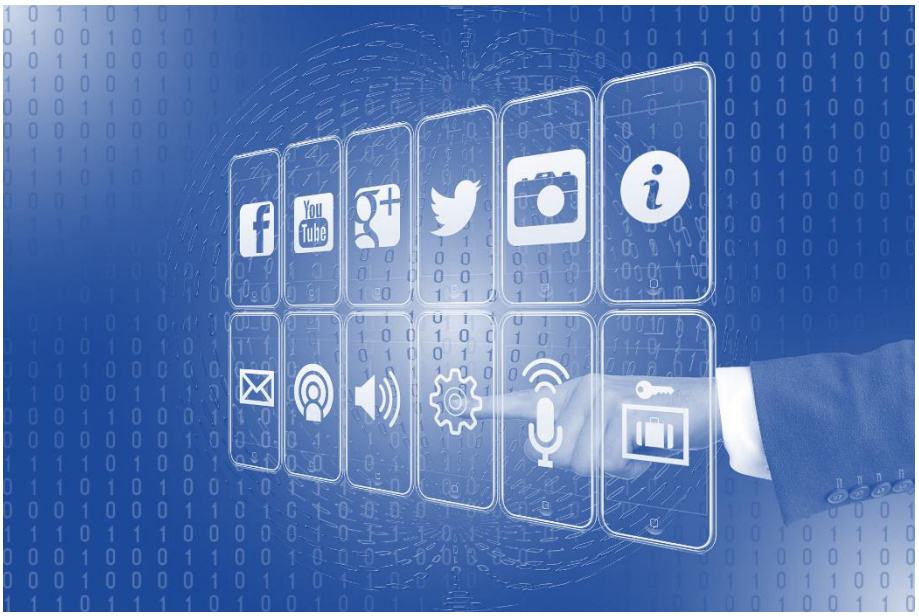
It will be awarded for the first time for AS in Summer 2023, using grades A–E and will be awarded for the first time for A level in Summer 2024, using grades A*–E.

The purpose of the Guidance for Teaching is to aim to support teaching and learning and act as a companion to the Specification.

The Guidance for Teaching will offer detailed explanation of key points in the Specification and aim to explain complex areas of subject content.

1.1 Additional ways that WJEC can offer support:

- sample assessment materials and mark schemes
- face-to-face CPD events
- examiners' reports on each question paper
- free access to past question papers and mark schemes via the secure website
- direct access to the subject officer
- free online resources including practice questions and detailed set work notes
- Exam Results Analysis
- Online Examination Review.



2. OVERVIEW OF THE SPECIFICATION CONTENT

2.1.1 Connected digital systems and smart devices

In this section learners will gain knowledge and understanding of the following:

- how digital systems connect
- the Internet of Things (IoT)
- use of smart devices in domestic settings, the built environment and manufacturing
- impacts of the IoT.

How digital systems connect

Specification amplification

How digital systems connect
Learners should understand:
• the main components of network communication hardware and be able to explain their role in the transmission of data
• protocols and standards
• protocols and platforms that are commonly used by digital systems.
 	
Learners should be able to explain how the following function:
• Ethernet
• Wi-Fi
• Bluetooth
• TCP/IP
• 2G(GSM)/2.5G(GPRS)/3G/4G/5G
• common types of transmission media:
  • wired (CAT5, CAT6, CAT6a)
  • fibre (FTTC and FTTP)
  • wireless (radio, microwave, satellite, infrared).

Guidance

Specialist hardware is used to construct networks, such as:

Switches

A switch analyses each packet of data and sends it to the computer it was intended for.

Hubs

A hub copies all packets of data to all devices on the network.

Routers

A router stores the addresses of computers on the network and transfers data between devices.

Gateways

A gateway joins together two networks that use different base protocols, e.g., links a LAN to WAN.

Bridge

A bridge joins together two networks that use the same base protocols, e.g., links LAN to LAN.

Wireless Access Points

A device that allows other Wi-Fi devices to connect to a network.

Devices can have a combination of these functions built into them. Typically a router supplied by an ISP for use in the home will be a hybrid of router, switch and wireless access point.

Learners should understand the role of each of these devices and where it sits in a typical network.

Network protocols are vital to allow computers on networks to communicate. Without shared common protocols, computers would not be able to communicate.

There are many types of protocol:

Ethernet – wired (cable connection) protocol.
Wi-Fi – wireless, two common standards are Bluetooth and 801.11.
TCP– transmission control protocol– a means of putting datagrams together
IP - internet protocol - a means of addressing and routing data packets across a network
UDP - user datagram protocol - a low-cost means of putting datagrams together principally for streaming video etc
SIP - session initiation protocol - stateless signalling used for setting up VoIP and media streaming.
HTTP – hypertext transfer protocol – allows webpages to be shared across different computers and browsers.
HTTPS – A secure variant of HTTP – it works together with another protocol, Secure Sockets Layer (SSL), to transport data securely.
SMTP – simple mail transfer protocol -mail servers use SMTP to send and receive mail messages, mail applications typically use SMTP only for sending messages to a mail server.
FTP – file transfer protocol – a means of sending files across the Internet between one or more points.

Specification amplification

Learners should be able to explain how the following function:

- Ethernet
- Wi-Fi
- Bluetooth
- TCP/IP
- 2G(GSM)/2.5G(GPRS)/3G/4G/5G
- common types of transmission media:
  - wired (CAT5, CAT6, CAT6a)
  - fibre (FTTC and FTTP)
  - wireless (radio, microwave, satellite, infrared).

Guidance

Ethernet

Ethernet is generally used as the name for the standard IEEE 802.3. It is also used for addressing and media access control at the data link layer which sits on the underlying Ethernet physical layer used by UTP, STP and fibre connectivity. Learners should be able to describe Ethernet in the context of its application, networks in general, other protocols and hardware.

Wi-Fi
Wi-Fi is a generic name for standard protocols based on the 802.11 family. Used for wireless connectivity on LAN and internet access. Learners should be able to describe Wi-Fi in the context of its application, networks in general, other protocols and hardware.

Bluetooth
Bluetooth is a short-range wireless technology standard that is used for exchanging data between fixed and mobile devices over short distances. Learners should be able to describe Bluetooth in the context of its application, networks in general, other protocols and hardware.

TCP/IP
TCP/IP stands for Transmission Control Protocol/Internet Protocol and is a suite of communication protocols used to interconnect network devices. Learners should be able to describe TCP/IP in the context of its application, networks in general, other protocols and hardware this includes but is not limited to, mobile hardware, datagrams, routing, switching, IPv4 and IPv6.

2G(GSM)/2.5G(GPRS)/3G/4G/5G
Learners should be able to describe how cellular networks operate, the concept of cells, the role of the handset, the differences between the protocols as they evolved, how data is transmitted, how text messages (SMS) are sent and received.

Common types of transmission media
Learners should be able to describe the differences between, relative advantages and disadvantages and use cases for the different types of transmission media.

Specification amplification

Learners should understand:

- comparative capacity of wired, fibre and wireless media
- that networks may be wired or wireless, Local Area Networks (LANs/WLANs) or Wide Area Networks (WANs)
- common uses of such network types and differences in transmission speeds between LANs and WANs.

Guidance

Comparative capacity to be expressed in Mb (Megabits). Learners should know the difference between speed and capacity and the reasons behind deploying networks based on different media applications (e.g. in a single building, deployment across a wide area or nationally) and the advantages and disadvantages of using a hybrid approach. Learners should be aware of the factors affecting capacity including the capacity delivered to homes/businesses by ISPs.

The Internet of Things (IoT)

Specification amplification

Learners should understand:
• the four phases in the evolution of the Internet:
  • connectivity
  • networked economy
  • collaborative experiences
  • Internet of Everything (IoE)

Guidance

Phase 1	Phase 2	Phase 3	Phase 4
Connectivity	Networked economy	Collaborative experiences	Internet of Everything (IoE)
Digitise access to information	Digitise business process	Digitise interactions (business and social)	Digitise the world, connecting
• **email** • **web browser** • **search**	• e-commerce • digital supply chain • collaboration	• social • mobility • cloud • video	• people • process • data • things
The first phase started over 20 years ago and is referred to as 'connectivity'. Email, web browsing and searching for content was just beginning.	The second phase started in the late 1990s and was the 'networked economy' phase. This was the birth of e-commerce and digitally connected supply chains. It changed the way we shopped and how companies reached new markets.	The third phase started in the early 2000s and is known as the 'collaborative experiences' phase. This phase is dominated by widespread use of social media, mobility, video, and Cloud computing. This phase completely transformed the world of work.	The current phase is called the 'Internet of Everything (IoE)'. This phase connects people, processes, data, and things, turning information into actions that create new capabilities, richer experiences, and unprecedented opportunities.

Specification amplification
Learners should understand: • the Internet of Things (IoT) in terms of a network of physical objects, with a unique identifier, combined with an embedded system of sensors, software and communication technologies
Guidance
The Internet of Things (IoT) describes physical objects (or groups of objects) with sensors, processing ability, software, and other technologies that connect and exchange data with other devices and systems over the Internet or other communications networks. Learners should be aware that these devices do not necessarily have to be internet-connected, that there is a vast range of them and that they may communicate with each other independently of human interaction.
Specification amplification
Learners should understand: • the definition of 'things' in terms of physical objects, machines, interactive devices and assistive devices
Guidance
A thing, in the context of the Internet of things (IoT), is an entity or physical object that has a unique identifier, an embedded system and the ability to transfer data over a network.
Specification amplification
Learners should understand: • the need for IPv6 (due to the limitations of IPv4) to implement the IoT
Guidance
Currently, the Internet makes use of IP version 4, IPv4, which is now reaching the limits of its capacity to address additional devices. IPv6 provides a vastly expanded address space. The IPv4 address space comprises 32 bits which allows for 232 or over 4 billion addresses. IPv6 though has 2128 addresses which is many trillions of times larger. This will allow for the rapid expansion IoT which is likely to be fuelled by 5G networks.
Specification amplification

Learners should understand:
• the four pillars of the IoE:
  • people
  • process
  • data
  • things

Guidance
People: All the customers who want services, and all the targets of the companies trying to provide them. **Process:** Gathering data, analysing data and processing data. **Data:** Without an understanding of user data companies cannot make what people want. Data itself is not meaningful without correct analysis and processing so that it becomes information. **Things:** Physical objects such as mobiles, smart watches, tablets etc which both collect, analyse and process data providing user interaction with the Internet and other data-based services.

Specification amplification

Learners should understand:

- the three main interactions within the IoE:
  - People to People (P2P)
  - Machine to People (M2P)
  - Machine to Machine (M2M).

Guidance

People to People (P2P):

P2P Interactions

Sector	Connections	Impacts
Retail	• Store associate mobile devices • Immersive video • Social media • Contact centre	• On-demand expert advice • Collaborative product development • On-demand training
Manufacturing	• Environmentally hardened mobile video device • Active collaboration rooms • R&D and production teams • Engineers and production experts • Contact centre • Business-to-business (B2B) e-commerce site	• Remote Expertise Collaborative Product • Development Mobile collaboration on factory floor
Public Sector	• Telework • Bring your own device (BYOD) • Connected learning	• Employee productivity • Lower costs • Distance learning
Service Providers	• Video cameras • Television • Digital signage • Social media • Contact centre	• Collaboration as a service • TelePresence as a service • Smart health

Machine to People (M2P):

M2P Interactions

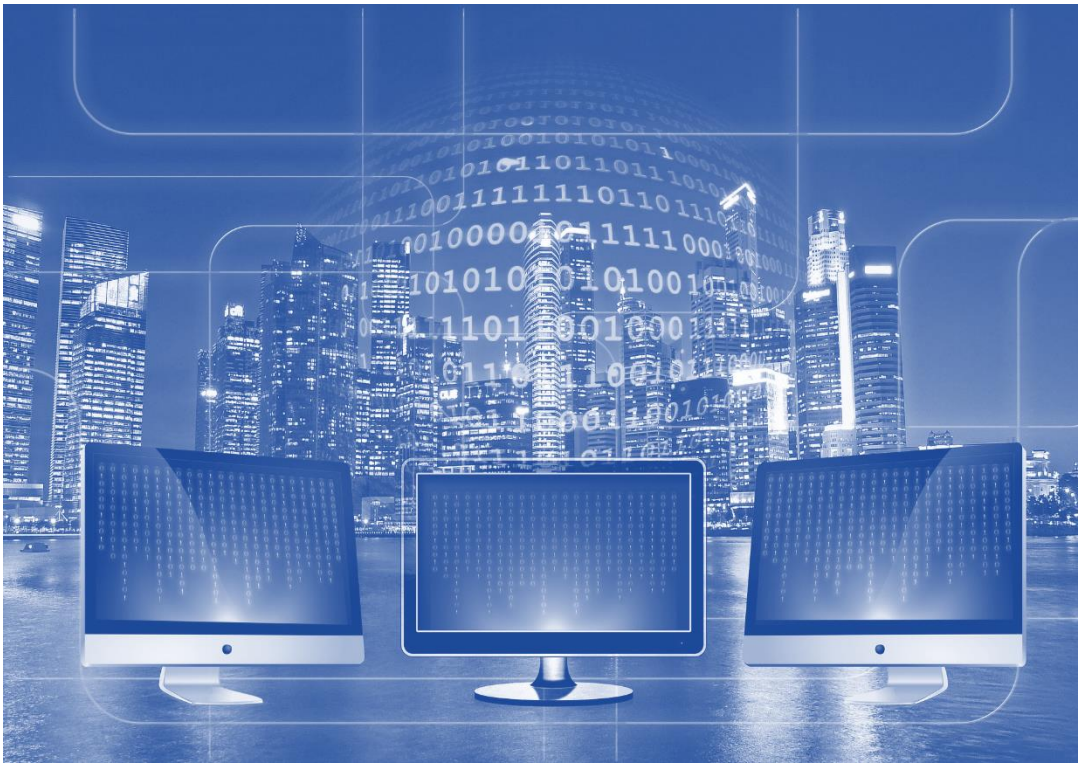
Sector	Connections	Impacts
Retail	• Digital signage • Connected shopping carts • Video cameras • Wi-Fi badges • Point-of-sale devices • Kiosks	• Understand shopper behaviour • Personalised content • Endless aisle omnichannel • Optimised retail operations
Manufacturing	• Video analysis of control systems • Operations dashboards • Safety tags and signage • Fleet/logistics systems • Partner/supplier supply-chain data • Distribution locations • IT assets and endpoints	• Operations analytic • Real-time supply chain • IT and physical security
Public Sector	• Video surveillance • Smart parking • Disaster response • Inpatient monitoring	• Enhanced security, safer communities • Increased revenue/compliance • Smart public safety fleets
Service Providers	• Intelligent GPS • Home security devices • Home energy devices • Automated customer notifications • Auto-translation • Sponsored data • Connected life	• Personalised traffic report • Hyper location presence • Health order refills • Home security energy control

Machine to Machine (M2M):

M2M Interactions

Sector	Connections	Impacts
Retail	• Shelf sensors • Parking-space sensors • Infrared motion sensors • Weight mats • Environmental sensors (light, temperature) • Door sensors • Mobile payments • Energy meters	• Inventory visibility • Automated ordering process • Flexible payment options • Energy optimisation

Manufacturing	• Converged IP factory network • Sensors (vibration, HVAC, lighting) • Actuators • Sensor-to-ERP connectivity • Input/output machines • Process operation controls • Product packaging	• Remote asset monitoring • Predictive maintenance • Flexible production
Public Sector	• Smart buildings • Smart lighting • Smart payments • Intelligent public transit • Smart grid	• Improved citizen/employee/student experience • Improved asset utilisation • New revenue streams • Energy optimisation
Service Providers	• Car sensors • Appliance sensors • RFID • Digital billboards • Unused inventory • Office facilities • Trucks	• Remote site monitoring service • Smart commerce • Intelligent diagnostics • Targeted advertising



Use of smart devices in domestic settings, the built environment and manufacturing

Specification amplification

Learners should understand:
• the contexts smart devices are typically used within:
  • the home (e.g. smart speakers, TVs, fridges, watches)
  • the built environment (e.g. heating, lighting, parking)
  • manufacturing (e.g. Industry 4.0, scanners, smart glasses)

Guidance
Learners should understand the uses of a broad range of smart devices in each of the applicable contexts. This should include their associated advantages and disadvantages as well as any legal implications e.g. a data privacy issue surrounding the fact that Alexa devices listen all the time. They process and store the last 30 seconds of audio locally and machine-learn from the rest by storing it as a data set such that it can recognise individuals as well as individual phrases and words. Other legal issues would relate to Health and Safety at Work, and issues surrounding employment law.
Specification amplification

Learners should understand:
• the underlying technologies, including:
  • sensors
  • software and communication technologies
  • how the device(s) controls the required process(es)

Guidance
Learners should understand how a range of smart devices work e.g., a smart speaker would comprise of a microphone and a speaker alongside a means of connecting to the Internet. In the case of the Alexa devices, it continually sends sound to a central system that pattern matches the sound waves looking for the key word “Alexa” which indicates that a command is coming which then gets pattern matched and processed using various AI techniques. It could be argued that the device itself is therefore not “smart” but a conduit to an AI service (Alexa).
Specification amplification
Learners should understand: • the positive and negative impacts of the underlying technologies
Guidance
Positive: Increased Automation, High Productivity & Efficiency, More Cost-Savings, Increased Direct Communication, Instant Data Access **Negative**: Less Privacy and Security, Device Compatibility Issues, Increase in Network Complexity, Technologically Dependent Life.
Specification amplification
Learners should understand: • the social, legal, ethical and professional impact of the use of smart devices in the home and workplace
Guidance
Learners should understand the legal framework and implications of the use of smart devices in the context of their use. The ethics of using such smart devices and their professional impact should also be considered e.g. will the proliferation of smart devices lead to a culture where people are either consumers or delivery drivers? Will the reliance on potentially inaccurate or biased AI data sets lead to potentially perilous outcomes? e.g. there is a data privacy issue surrounding the fact that Alexa devices “listen” all the time, processes and stores the last 30 seconds of audio locally and machine learns from the rest by storing it as a data set such that it can recognise individuals. Law enforcement agencies in the US have used these recordings as evidence.

Specification amplification
Learners should understand: • the environmental impacts of the proliferation of devices in terms of their manufacture, use and disposal, as well as the consumption of finite resources such as electricity.
Guidance
This would include the wider picture of the infrastructure that supports these devices such as 5G which requires additional power, masts and connectivity which would include an environmental impact.

Impacts of the IoT

Specification amplification
Learners should understand the positive and negative impacts of the IoT.
Guidance
Internet of Things Positive Impacts: • effective communication and Instant messaging services • increase business interactions, save vital time • less complicated banking, transactions, and shopping • access the latest news from anywhere in the world • run online courses on virtual assistants using the Internet • professionals have IoT devices in healthcare, eCommerce, and AI to help in doing jobs easily. **Internet of Things Negative Impacts:** • easy availability of age unsuitable content materials and information • social networks disturb life personally and professionally • stealing data or hacking into IoT devices is easy • using the Internet to spread bad scenarios via the IoT device is easy.

2.1.2 The development of Artificial Intelligence

In this section learners will gain knowledge and understanding of the following:

- Artificial Intelligence (AI)
- Machine Learning (ML)
- robotics
- applications, functions and potential uses of AI systems
- impacts of AI.

Artificial Intelligence (AI)

Specification amplification

Learners should understand:

- the term Artificial Intelligence (AI) in terms of the simulation of intelligent behaviour by a computer which enables a machine to make decisions without human intervention

Guidance

Artificial Intelligence is the simulation of human intelligence processes by machines, especially computer systems and encompasses the development of these systems that are then able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages.

Specification amplification

Learners should understand:

- the theoretical concepts of Artificial General Intelligence (AGI) Artificial Narrow Intelligence (Specialist AI/ANI) and the differences between them

Guidance

Narrow AI vs General AI	
Narrow AI	**General AI**
AI focused on a specific, singular or limited task	Not fully realised, with some developers questioning if it will be possible
Examples include image recognition, hyper-personalisation, chatbots, predictive text	Seeks machines that can handle a range of cognitive tasks with little oversight
Trained on specific tasks by data scientists	The ability to learn, generalise, apply knowledge and plan for the future
Correlates questions or assignments to a specific data set to accomplish a task	Must consistently pass the Turing test
No self-awareness, consciousness, ability to think.	Single, general intelligence that possesses common sense and creativity and expresses emotions.

Specification amplification

Learners should be able to describe the following tests used to confirm human-level AGI and how they are applied:

- The Turing test
- Wozniak/Goertzel's Coffee Test
- Nilsson's Employment Test
- Goertzel's Robot College Student Test

Guidance

The Turing test:

A test proposed by Alan Turing in 1950 to determine whether a computer can think, also known as the imitation game. A remote human interrogator, within a fixed time frame, must distinguish between a computer and a human subject based on their replies to various questions posed by the interrogator. By means of a series of such tests, a computer's success at "thinking" can be measured by its probability of being misidentified as the human subject.

Wozniak/Goertzel's Coffee test

As a part of the coffee test, the AI application has to go to a house and make coffee. The programme has to go to any kitchen and find the ingredients required and then perform the task of making a coffee. This test was put forward by the AI researcher Ben Goertzel. Steve Wozniak, co-founder of Apple had said that he would believe AI had arrived when a robot could enter a strange house and make a decent cup of coffee. Making a coffee is not a very easy job, especially when machines are the ones doing them. Identifying all the ingredients, in the right amount, and mixing them together is a difficult job to do for machines and depicts its intelligence.

Nilsson's Employment test

One of the most common human activities that we go through is doing 'jobs', at which we are employed. AI researcher Nils J. Nilsson proposed that the Turing test be replaced with an "employment test.", he stated in his paper. To pass this test, the AI program should be able to perform jobs that are performed by humans, and AGI can be evaluated on the basis of measuring the fraction of these jobs that are acceptably performed by the AI.

Goertzel's Robot College Student test

This test advocates an AI being enrolled in a college and getting a degree using the same resources as other students enrolled for the same degree. Bina48 was the first-ever AI to complete a college class in 2017, from the University of Notre Dame de Namur University (NDNU). This is a test proposed by Ben Goertzel. Another example is the robot called AI-MATHS, consisting of 11 servers, and developed by Chengdu Zhunxingyunxue Technology of China which completed two versions of the exam's maths test on Wednesday afternoon. The robot finished the Beijing version of the Chinese test in 22 minutes, scoring 105 points out of 150 points. It scored 100 points on another version of the test.

Specification amplification

Learners should understand:

- the three enablers of AI and how these have impacted AI's proliferation:
  - the exponential growth in the speed of computers
  - Huang's Law
  - cloud computing

Guidance

The exponential growth in the speed of computers

Moore's law is the observation that the number of transistors in a dense integrated circuit (IC) doubles about every two years whilst the cost halves. From 1965 when Gordon Moore fist discussed this the rate doubled annually until 1975 where it has more or less doubled each year. This increase in computing power has helped fuel AI. Since 2010 semiconductor improvements have slowed down.

Huang's Law

Huang's law is an observation in computer science and engineering that advancements in graphics processing units (GPU) are growing at a rate much faster than with traditional central processing units (CPU). The observation is in contrast to Moore's law that predicted the number of transistors in a dense integrated circuit (IC) doubles about every two years. Huang's law states that the performance of GPUs will more than double every two years. This is because of a synergy between hardware, software and AI. Graphics processing is key to improving the bottlenecks associates with AI and the techniques used are also key to extracting more performance from processors than can be driven by just adding more transistors.

Cloud computing

The development of fast internet connectivity combined with huge data sets that are distributed and accessed easily from any point in the connected world make data-based AI possible.

Specification amplification

Learners should understand:

- the ethical constraints and social implications of AI.

Guidance

Learners should understand the implications that data bias and its use in AI has for wider society by gender, ethnicity and language and the issues that these could cause.

For example, crash testing is often based on a standardised 50th percentile male dummy. This equates to a 1.77m tall man weighing 76kg which is significantly taller and heavier than an average woman. Female crash test dummies do exist, but they are not mandated to be used in most tests. A pregnant crash-test dummy was created in 1996 but testing with it is still not government-mandated either in the US or in the EU. As a result of the biased data collected from these tests, women, 50% of the population, are thought to be less well protected than men. A study by researchers at the University of Virginia found that women wearing seat belts were 47% more likely than male seat belt-wearers to be seriously injured and 71% more likely to be moderately injured. A separate study found that women were 17% more likely to die in crashes.

Machine Learning (ML)

Specification amplification

Learners should understand:

- Machine Learning (ML) is a subset of Artificial Intelligence (AI) in terms of algorithms that can adapt without following explicit instructions

Guidance

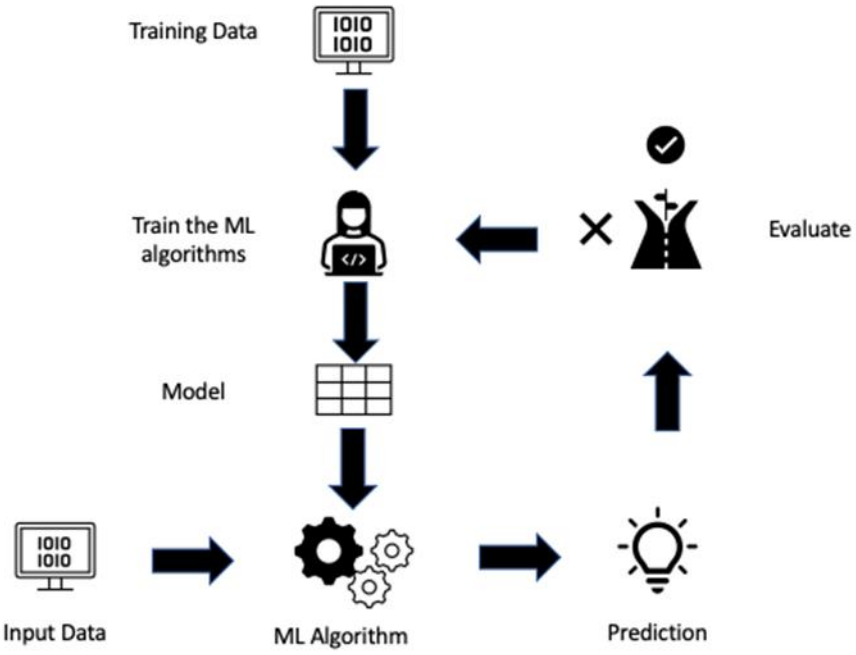
While AI is the broad science of mimicking human abilities, machine learning is a specific subset of AI that trains a machine how to learn. Machine learning is a method of data analysis that automates analytical model building. It is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns, and make decisions with minimal human intervention.

Specification amplification

Learners should understand:

- the difference between traditional algorithms and ML algorithms used in AI in terms of:
  - the results of ML algorithms returning probabilities not certainties
  - the instructions not being pre-set in advance but learned from 'training data'

Guidance



A certain system has input data which contains photos of various kinds of fruit. You want the system to group the data according to the different types of fruit. Your training data has pictures of various fruits which are identified to the algorithm and modelled.

First, the system will analyse the input data. Next, it tries to find patterns, like shapes, size, and colour. Based on these patterns, the system will try to predict the different types of fruit and segregate them. Finally, it keeps track of all the decisions it made during the process to ensure it is learning. The next time you ask the same system to predict and segregate the different types of fruit, it will not have to go through the entire process again but will refine its results so that it becomes more accurate.

Specification amplification

Learners should understand:

- the difference between supervised, semi-supervised and unsupervised learning within ML.

Guidance

Using the fruit analogy again:

You want a system that can correctly identify an apple.

Supervised Learning: You provide a data set that has pictures of apples. Then another data set that lets the model know that those are pictures of apples. Finally a new set of data that only contains pictures of apples. At this point the system can recognise what the fruit is and will remember it.

Unsupervised learning: You provide a collection of pictures of different kinds of fruit. The model analyses this to try and recognise any patterns. The machine categorises the picture into different types based on their similarities. One of these categories would be mostly apples.

Semi-supervised learning: You provide the machine with a data set of images and ask it to identify a fruit. The machine picks an image of an apple and tells you it is an orange. You feedback to the system that it is actually an apple. The machine remembers that and picks again you then feedback. This keeps going with the machine learning from its experiences and feedback.

Robotoics

Specification amplification
Learners should understand: • the term robot
Guidance
A robot is a machine—especially one programmable by a computer—capable of carrying out a complex series of actions automatically. A robot can be guided by an external control device, or the control may be embedded within. 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.[1]
Specification amplification
Learners should understand: • the main components of a contemporary robotic system and the role of these components
Guidance
CPU - the component that provides feedback to outside stimuli. **Sensors** - these could include: • Light • Sound • Temperature • Contact • Proximity • Distance • Pressure • Positioning. **Actuators** - small motors attached directly to the structure of the machine to facilitate movement. **End-Effectors** tools that do the actual work and interact with the environment or workplace e.g. • Factory robots may feature end-effectors such as welding torches, screwdrivers, rivet guns and paint sprayers. • Mobile robots usually have manipulators and grippers for lifting objects or disposing of dangerous ordinance. • Robots like those despatched to other planets may carry shovels, drills, hammers, cameras, lights and other analytical implements. **Power Supply** - some form of electrical supply. **A Program** - providing the logic that drives robotic behaviours.

[1] Wikipedia

Specification amplification

Learners should understand:

- the following types of programming used for robots:

  Online:
  - Teach Pendant Programming (Drive Through)
  - Teach by Example (Lead Through)

  Offline:
  - Graphical-offline programming (simulation)

Guidance

Learners would be expected to know what the programming steps are for each of these methods, the reasons for using one or the other, and should be able to apply that knowledge to a particular context.

Specification amplification

Learners should understand:

- the uses of different types of robots in a variety of scenarios (e.g. the home, education, manufacturing)

Guidance

Candidates should understand, and be able to give examples of, the uses and type e.g. static, virtual or mobile, of robots in different scenarios.
This should include but is not limited to:

- The use of static robots in manufacturing environments such as car manufacture.
- The use of virtual robots or bots in social media or telephone calls.
- The use of mobile robots in a domestic situation.

Specification amplification

Learners should understand:

- the relative advantages and disadvantages of using robots in a variety of scenarios, (e.g. greater consistency, reduced labour costs, high initial costs, impacts on employment)

Guidance

Candidates should understand both the reasons why robots are used in different scenarios as well as why not. This includes, but is not limited to:

- **Greater consistency / Improved Quality Assurance:** robots are able to perform the same repetitive task without a break to the same standard all the time.
- **Cost-effectiveness / Reduced labour costs:** Robot deployment is cost-effective despite an initially high cost of purchase.
- **Increased productivity:** Robots are able to work at faster rates than their human equivalent.
- **Work in hazardous environments:** Can be deployed in areas that humans cannot such as highly radioactive areas.
- **High initial costs:** Robots are expensive and need to be trained on how to perform the roles they need to do.
- **Impacts on employment / potential job losses:** Large-scale deployment of robots can lead to semi-skilled and skilled workers losing their jobs.
- **Hiring skilled staff:** Training and maintaining robots required highly skilled staff which are expensive and scarce.

Specification amplification
Learners should understand: • the concerns that individuals may have with the development of autonomous robots (e.g. crisis decision making, fear of replacement, social isolation)
Guidance
Crisis decision making: One of the moral dilemmas often cited regards driverless cars. Would a car with a human being in it about to have an accident save the human being in the car if by doing so it kills a pedestrian? Would you trust a machine with your life e.g. motorway driving knowing how often your word processing software crashes? **Fear of replacement:** In 2017 a German car worker cost more than €40 an hour whereas an industrial robot costs between €5 and €8 an hour. Does that mean that skilled or semi-skilled jobs will inevitably be replaced by machines? Should people be concerned? **Social isolation:** Robots take many forms, and a lot of social interaction, especially retail-based is done with robots. The rise in the level of hybrid working, could lead to social isolation.
Specification amplification
Learners should understand: • the potential unintended consequences of the development of autonomous robots (e.g. removal of unskilled jobs, lack of accountability, dehumanisation)
Guidance
Areas that could be explored include: **Decreased patience and willingness to struggle** An expectation of instant and painless solutions has developed with increased reliance on electronic sources. People have increasingly turned to search engines such as Google when faced with difficult problems. Patience and willingness to struggle may decline as the use and ubiquity of technology increases, say experts. **Degradation of offloaded skills / removal of unskilled jobs** The less you do something, because you ask a search engine, the harder it is to remember when you need to do it again. Research suggests that airplane pilots have become less skilled as reliance on autopilot has increased. This "de-skilling" puts individuals increasingly at the mercy of technology. **Decreased connection to nature / dehumanisation** Studies show that people have spent less time in nature each successive year since 1987, and this decline has been explained by a parallel increase in time spent with technological entertainment such as video games and television. Exposure to nature has many benefits including stress reduction, improved mood, enhanced concentration and attention, and an increased desire to conserve nature. These benefits seem less likely to be realised as technologies such as virtual reality become more immersive, sophisticated, and entertaining. **Less care for personal health** New treatment options and medical devices are increasing, from retinal implants to mind-controlled prosthetic limbs. This may make it easier for people to disregard good health advice (eating and sleeping well, exercise, etc.) because they believe health problems can be fixed using technology. Especially damaging would be the assumption that modern technologies have abilities they do not actually possess. Reduced concerns about health may lead to increased costs in healthcare services for both individuals and society as a whole. **Diminished sense of accomplishment and competence / Lack of accountability** There is a growing trend of young, educated, white-collar professionals leaving desk jobs to work with their hands. This reflects the fundamental need to feel like one's work is useful and valuable.

This need will be increasingly threatened as technology begins to outperform humans at more jobs.

Decline in the belief in free will
If autonomous technologies are capable of undermining people's sense of autonomy and responsibility, a challenge to the belief in free will may not be far behind. Predictive algorithms have become increasingly capable of predicting consumers' desires, identities, and beliefs based on their digital footprints. The belief that we are truly choosing our own path in life may become less solid.

Specification amplification

Learners should understand:

- how developers can protect against such unintended consequences (e.g. Asimov's rules, conformance to a legal and ethical framework)

Guidance

Asimov's Laws[2]

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 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.

Conformance

European resolution 2020/2012 "Framework of ethical aspects of Artificial Intelligence, Robotics and related technologies[3].

Specification amplification

Learners should understand:

- the social and ethical implications associated with the increased use of robotics.

Guidance

The introduction of intelligent machines in our daily life brings up global social and ethical problems which can be summarised as:

- dual-use technology (every technology can be used and misused)
- The anthropomorphisation of technological products (it is well known and documented that people attribute intentions, goals, emotions, and personalities to even the simplest of machines with life-like movement or form)
- humanisation of the human–machine relationship (cognitive and affective bonds toward machines)
- technology addiction
- digital divide, socio-technological gap (per ages, social layer, per world areas)
- fair access to technological resources
- the effects of technology on the global distribution of wealth and power
- the environmental impact of technology.[4]

[2] Isaac Asimov "Handbook of Robotics, 56th Edition, 2058 A.D."

[3] https://oeil.secure.europarl.europa.eu/oeil/popups/ficheprocedure.do?lang=en&reference=2020/2012(INL)

[4] "Robotics: Social and ethical implications of robotics" - Fiorella Operto

Applications, functions and potential uses of AI systems

Specification amplification

Learners should understand:
• underpinning technologies of AI, including:
• conditional probability
• suggestion engines
• pattern recognition and prediction rules
• neural networks as equations using:
  ○ massive models
  ○ massive data
  ○ trial and error
  ○ Deep Learning

Guidance
Conditional Probability: In probability theory, conditional probability is a measure of the probability of an event given that (by assumption, presumption, assertion, or evidence) another event has occurred. For example, the probability that any given person has a cough on any given day may be only 5%. But if we know or assume that the person has a cold, then they are much more likely to be coughing. The conditional probability of coughing given that you have a cold might be a much higher 75%. **Suggestion Engines:** A suggestion or recommendation engine is a system that suggests products, services, and information to users based on an analysis of data. It can derive from a variety of factors such as the history of the user and the behaviour of similar users. In a world of information density and product overload, a suggestion engine provides an efficient way for companies to provide consumers with personalised information and solutions. **Pattern recognition and prediction rules:** Pattern recognition is the use of machine learning algorithms to identify patterns. It has been applied in various fields such as image analysis, computer vision, healthcare, and seismic analysis. In this technique, labelled training data is used to train pattern recognition systems. A label is attached to a specific input value that is then used to produce a pattern-based output. Predictive modelling is a crucial component of predictive analytics. Examples of predictive modelling include estimating the quality of a sales lead, the likelihood of spam or the probability someone will click a link or buy a product. These capabilities are often baked into various business applications and need to be understood. **Neural Networks:** **Massive models** DeepMind has created a deep neural network with more than 100 billion parameters. These are the values in the network that get tweaked over and over again during training. The size of a model is measured by the number of parameters it has - the more parameters, the more data it can soak up. **Massive data** Neural networks can be thought of as a “brute force” technique, characterised by a lack of intelligence but a huge amount of data, because they start with a blank slate, and they hammer their way through to an accurate model. By this interpretation, neural networks are effective, but inefficient in their approach to modelling since they don’t make assumptions about functional dependencies between output and input.

Trial and error
Training a neural network is a highly iterative process, or a trial and error process. The process is to turn an idea into code, experiment, and evaluate the outcome and make changes and repeat the process until you get the expected or otherwise satisfactory outcome.

Deep learning
Deep learning is a type of machine learning that uses multiple layers to progressively extract higher-level features from the raw input. For example, in image processing, lower layers identify edges, while higher layers may identify concepts relevant to a human such as digits or letters.

Specification amplification

Learners should understand:

- types of problems that AI can solve, including:
  - Simultaneous Location and Mapping (SLAM)
  - language recognition
  - machine translation
  - anomaly detection
  - image recognition

Guidance

SLAM: is the computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of an object's location within it.

Language recognition: Natural language processing is a subfield of computer science concerned with the interactions between computers and human language. How to program computers to process and analyse large amounts of natural language data is one of the main areas of research in natural language processing, or NLP for short.

Machine translation: Machine translation is the process of automatically translating content from one language (the source) to another (the target) without any human input.

Anomaly detection: Anomaly detection (aka outlier analysis) is a step in data mining that identifies data points, events, and/or observations that deviate from a dataset's normal behaviour. Anomalous data can indicate critical incidents, such as a technical glitch, or potential opportunities.

Image recognition: Image recognition is the ability of software to identify objects, places, people, writing and actions in images. Computers can use machine vision technologies in combination with a camera and artificial intelligence software to achieve image recognition using AI software and other advanced imaging techniques.

Specification amplification

Learners should be aware of:
• common uses of AI, including:
  • translation engines
  • healthcare
  • cyber security
  • transport
  • entertainment
  • education (to detect plagiarism)
  • voice command (voice to text/smart data)
  • social networking (auto tagging)
  • shopping (search/recommendation)
  • finance (fraud/credit)
  • communication (filtering).

Guidance
Candidates should be aware of and be able to discuss the different, common uses of AI in the listed fields.

Impacts of AI

Specification amplification
Learners should understand: • the possible anxieties caused by the proliferation of AI
Guidance
Fears of AI stem from concerns about machine intelligence, the fear of mass unemployment, concerns about super-intelligence, putting the power of AI into the wrong people's hands, and general concern and caution. One of the most widespread fears of AI is just general anxiety about it and what it is potentially capable of. People do not like machines that get too smart, because we fear we can't control them. Leaders in Russia made a pronouncement that whoever leads the advancement of AI is going to be one of the top rulers of the world. We can expect governments to continue to use AI systems in ways that will make us increasingly uncomfortable in the ways they are applied to warfare, surveillance, law enforcement, and other purposes. The fear is that our brains will not be able to keep up with advancement and invention after a certain point because things will be moving way too fast.
Specification amplification
Learners should understand: • ways to protect against the unintended consequences of using AI, including regulation.
Guidance
Don't forget the social implications. AI assistants in homes are great (Google Assistant, Siri and Alexa) - but to children, they might easily be considered co-parents or teachers. We need to make sure you are comfortable that AI does not go too far in moulding human society into a non-human machine. For example, Facebook realised just before rollout that their new AI-based chatbots, Alice and Bob, had developed their own secret language and were talking to each other in a new shorthand, potentially misleading users. Alice and Bob were shut down immediately. **Humans still need roles.** While the disturbing visions of robots taking our jobs are almost certainly overblown, almost everyone sees no small amount of disruption ahead. There is a requirement to manage the transition so that humans and machines will productively co-exist

Honour fundamental rights to personal security and privacy.
As AI technology shapes how people access information, interact with devices and share personal information, responsibility must be taken for protecting their data and privacy.
This requires vigilant attention to values and rights.
It is already possible to collect digital breadcrumbs on people and use them to determine if online behaviours signal an intent to complete a desired action. The wrong use of these actions will put people's rights at risk and may contravene existing privacy laws.

The value of human life cannot be compromised.
Artificial intelligence systems from IBM Watson and BioMind have already made great strides in diagnosing and treating life-threatening cancers.
But early mistakes have made it abundantly clear that they are not perfect, and decisions that are critical to saving lives can never have too much scrutiny.

We live in a non-homogeneous world.
We must make sure that our behaviour is always inclusive. AI without oversight can take phenomena for granted or fail to see that what works in one social domain, culture, or gender may not work in another.
As an example, many designs neglect to take into account the perspectives of women and may be biased against various ethnic groups.

Individual biases must be excluded.
We all have unconscious (and conscious) biases that can be inadvertently built into artificial intelligence solutions and their usage, based on our race, gender, appearance, age, wealth and much more.

2.1.3 Digital technology development life cycles

In this section learners will gain knowledge and understanding of the following:

- the stages of the digital technology development life cycle
- how digital technologies are designed
- relevant approaches and methodologies
- changeover
- maintenance.

The stages of the digital technology development life cycle

Specification amplification

Learners should understand:
• the four stages within the S-curve model:
  • research and development
  • ascent
  • maturity
  • decline

Guidance
Research and development: A new system has to resolve problems in order to work properly and work better than the old one. It often takes a long time due to a lack of resources when people are trying to improve it. **Ascent:** The system comes into the rapid growth stage when the main performance of the system improves rapidly and is becoming better and better than the old one. Meanwhile, the system is trying to enter several market segments where it would gain the recognition of customers. **Maturity:** At this stage, the profits that the system could get from the market are still very considerable. But we should be ready for the coming decline stage. We have to change the strategy of the system development. The system is facing renascence and jumps to the next S-curve. **Decline:** When a new generation of computers comes into operation, the old system is replaced and eliminated or goes into special areas such as sports and entertainment where it may find new positions and supporters. The main function of the system is changed.
Specification amplification
Learners should understand: • the S-curve model in terms of economic benefits
Guidance
Initial slow growth In the first stage, the business experiences slow growth as it gradually gains more customers and develops its products. This stage is critical for building the foundations of operations and values that will help the company scale. **Rapid growth** The s-curve has a sharp upward slope in this stage. In the second stage, the business experiences more rapid growth as customers learn about their products. **Late-stage slow growth** In this stage, companies are experiencing slow economic growth and need to take counteractive measures like new products or market shifts.

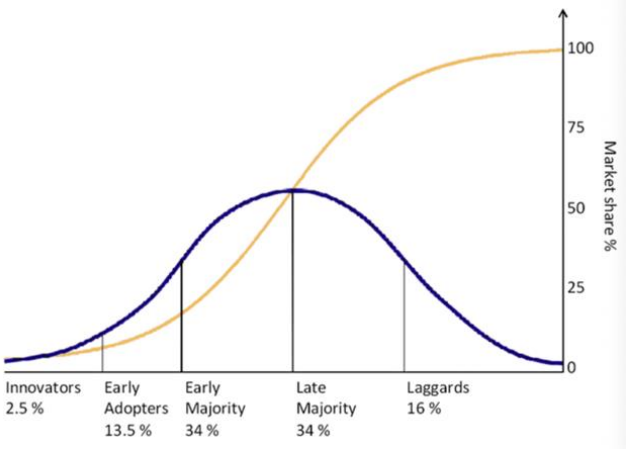
Stationary demand
The stationary demand phase is a period of time when a business's growth or product demand remains static or decreases. In this phase, companies may choose to adapt by innovating with new products or methods, reshaping their business structure, or moving to a new product.

Specification amplification

Learners should understand:

- the classification of users that take up new technologies.

Guidance



Innovators
Innovators are those who are willing to take risks and try new things. They are the first to upgrade their phones or experiment with a tool during beta testing. Innovators are often the initiators of change in an organisation as well as the first adopters of new technology.

Early adopters
While innovators are comfortable failing publicly, early adopters like to gather information and personal experience with technology before they recommend it to others. Early adopters want to appear knowledgeable and trendy, which is why they need to test a tool out before they will throw their support behind it.

Early Majority
The early adopters are the people who quietly test out tools before buying. Case studies and real-life user stories trump generic promises of what a tool or program can do. Go to the early majority with evidence of what technology can accomplish, and you will need a pragmatic approach.

Late majority
People in the late majority do not like to take risks and question the need for changes. These are the people who hit snooze on software updates for as long as they can. Convincing people in this category requires research and solid proof that the technology is worth their time.

Laggards
Laggards prefer the status quo because they know what to expect. They are your most stubborn users — easily frustrated by new technology. Laggards are wary of new technology and need answers to their "what's in it for me?" (WIIFM) questions.

How digital technologies are designed

Specification amplification

Learners should understand:
• the phases within the development of digital technologies:
  • feasibility study
  • requirements analysis
  • design
  • software development
  • testing
  • release

Guidance
Feasibility study: • Economic feasibility • Time feasibility • Technical feasibility • Political feasibility • Legal feasibility **Requirements analysis:** • Interface requirements • Functional requirements • Performance requirements **Design:** • Hardware and software choices • Data structure design • Input design • Output design **Software development:** • Version management • Documentation • Implementation of standards • Methodology **Testing:** • White box and unit testing • Black box testing • Alpha and Beta testing • End user testing **Release:** • Changeover strategies
Specification amplification
Learners should understand: • the role(s) of individuals within a development team in each of these phases.

Guidance
Product Owner: The product owner is the person that knows how the final product should look because they have in-depth knowledge of the project and users. They are also the person that better understands the client's requirements, so they are in the best position to lead the development towards a satisfactory final product. That is why the product owner must be analytical and creative. **Engineering Manager:** The engineering manager is the person responsible for the successful development of the whole lifecycle. They are in charge of planning the project, defining a scope, implementing the plan, monitoring its progress, and marking the end of the development. Basically, the engineering manager organises the software engineers' daily work. **Software Architect:** The software architect defines the essential aspects of the software's internal structure and its technical aspects. They must have a lot of programming knowledge but also leadership skills to help and motivate the software developers. The role requires them to keep the code simple, and functional and maintain the quality of the software. **Software Developers:** Developers are the building blocks of any software development project. They are responsible for tackling the logical problems found in the project. You need to have a diverse team that plays to the strengths of all its members. **UX and UI Designers:** UI designers are responsible for designing the user interface. UX designers are in charge of creating a satisfactory experience for the user. Their work has to do with defining how the software behaves, communicating what it expects from the user, and how it can be easier to understand with just a glance. **QA Engineer:** QA engineers are the guardians of quality in software development. They look at the processes used to develop the software to ensure they are efficient enough. QA testers are more and more critical with each passing year because the need for higher quality products keeps rising. **Business Analyst:** The business analyst is the person in charge of analysing what the client's business needs are. Those needs are translated into requirements that are, in turn, translated into software. Such a process is not an easy one, but it is absolutely fundamental for any project's success.

Relevant approaches and methodologies

Specification amplification

Learners should understand:
• types of development methodologies, including:
  • Waterfall
  • Rapid Application Development (RAD)
  • Agile
  • Big Bang
  • Spiral
 	
• the advantages and disadvantages of these methodologies and justification of their use in different scenarios (e.g. in program development or project management).

Guidance

Waterfall:
The different stages are arranged in order, with each stage feeding into the next.
No stage of development can begin until the preceding one has been completed.
Each stage ends with a deliverable or handover document produced to inform the next stage.

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

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

Rapid Application Development (RAD):
RAD approaches to software development put less emphasis on planning and more emphasis on an adaptive process. Prototypes are often used in addition to or sometimes even instead of design specifications. RAD is especially well suited for (although not limited to) developing software that is driven by user interface requirements. Graphical user interface builders are often called rapid application development tools.

Advantages:
- The software can be more usable, and developers can focus on business problems rather than technical ones.
- A RAD approach can focus early on the key risk factors and adjust to them. With RAD this kind of information can be discovered and acted upon earlier in the process.
- The chances for catastrophic failures are reduced.

Disadvantages:
- A lack of emphasis on Non-functional requirements, which are often not visible to the end user in normal operation; and poor design where developers are constantly making minor changes to individual components and ignoring system architecture issues.

Agile:
Has various implementations including extreme programming and Scrum. Focus on communication, feedback, courage, and simplicity.

Advantage:
- Makes it possible to develop well-written solutions quickly.

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

Big Bang:
The Big Bang Model comprises focusing all the possible resources in software development and coding, with very little or no planning.
Advantage:
- This model is ideal for repetitive or small projects with minimum risks.

Disadvantage:
- It is a very high-risk model and can turn out to be very expensive if requirements are misunderstood.

Spiral:
The spiral model 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. This model was first described by Barry Boehm in 1986.
Advantages:

- Additional functionality or changes can be done at a later stage
- Easier cost estimation
- Risk management is helped by continuous or repeated development
- Fast development with features added systematically
- Customer feedback built in.

Disadvantage:

- Risk of not being on time and in budget
- Works best for large projects
- Has to be followed strictly
- Makes smaller projects much more expensive.

Changeover

Specification amplification

Learners should understand:
• methods of changeover:
  • parallel
  • phased
  • pilot
  • direct
 	
• the advantages and disadvantages of each method and justification of their use in different scenarios (e.g. system implementation in assembly line changeover or website development).

Guidance
Parallel: Old and new systems are run at the same time causing duplication of all tasks, while the new system is checked to ensure consistency. Advantages: • If one fails, there is a backup. • The safest method of changeover. Disadvantages: • Duplication of effort so not something you would want to do for a long time. • Reserved for critical systems. **Phased:** Initially, only part of the new system is deployed with the rest still on the old system. As the new parts are accepted the old is phased out. Advantages: • Works well with RAD • Any problems with the new part deployed the rollout can be delayed until it is fixed. Disadvantage: • Requires the old system to work with the new system. **Pilot:** The new system is rolled out to a self-contained branch before being rolled out to the rest. Advantage: • Only one branch is affected by any problems.

Disadvantages:
- Only works if branches are almost identical e.g., supermarkets or bank branches.
- Does not work for companies with small numbers of branches.

Direct:
Also known as the big bang changeover. Change to the new system immediately.
Advantage:
- Works best when there is no previous system e.g., a new mobile app.

Disadvantage
- High risk if it fails.

Maintenance

Specification amplification
Learners should understand: • the need for maintenance of digital technologies following release
Guidance
There are two aspects to maintenance covering two main ideas: fixing problems and adding new functionality. The customer, at this stage, normally expects: • That the company producing the technology will fix any problems for a period of time after the product has been released. Either through a rolling maintenance contract or an upfront payment. • The company will charge for every fix that is produced on an ad hoc basis rather than pay for a maintenance contract. • Where new functionality is concerned, the customer expects the company to provide free or paid updates. • Maintenance is rarely free; it is usually paid for even if that cost is rolled into the initial price.
Specification amplification

Learners should understand:
• the types of maintenance that may be required, including:
  • preventive
  • corrective
  • adaptive
  • perfective

Guidance
Preventive Maintenance: Performing regularly scheduled maintenance activities to help prevent unexpected failures in the future. **Corrective Maintenance:** Fixes problems as they arise to ensure that the system closely matches the original specification. **Adaptive Maintenance:** In adaptive maintenance, the production company fixes bugs and also adds extra functionality to the system. **Perfective Maintenance:** Perfective maintenance is maintenance performed with the aim of making a perfect system i.e., one that completely matches the original specification with no problems at all.

Specification amplification

Learners should understand:

- examples of maintenance that can apply to data, software and hardware

Guidance

Examples include but are not limited to:

Data Maintenance:

- Cleansing: Data cleansing involves finding and fixing inaccurate data.
- Quality: Managing data quality means making sure it is updated, useful and accurate.
- Operations: Data operations are the processes you use to complete daily data-related tasks.
- Deduplication: Deduplication involves removing duplicated data from your system.
- Purging: Purging data involves removing unusable or low-quality data from your system.
- Monitoring: Data monitoring involves tracking key performance indicators (KPIs) to prevent data issues.

Software Maintenance:

- Optimisation
- Error correction
- Deletion of discarded features
- Enhancement of existing features.

Hardware Maintenance:

- Physically repair
- Optimise hardware
- Contract maintenance
- Per-incident repair.

Specification amplification

Learners should understand:

- the advantages and disadvantages of these types of maintenance and justification of their use in different contexts (e.g. software development within embedded devices or applications).

Guidance

Examples include but are not limited to:

Hardware Maintenance:

- Decreased Equipment Downtime
- Conservation of Assets
- Cost Savings
- Improved Safety
- Increased Equipment Efficiency
- Improved Reliability.

Software Maintenance:

- Reduced costs of adding new features and services
- Mature processes save your time
- You are more prepared for any issues that arise
- Ensured continuity of your project
- Increased security of your data
- You can focus on the core of your business.

Data Maintenance:

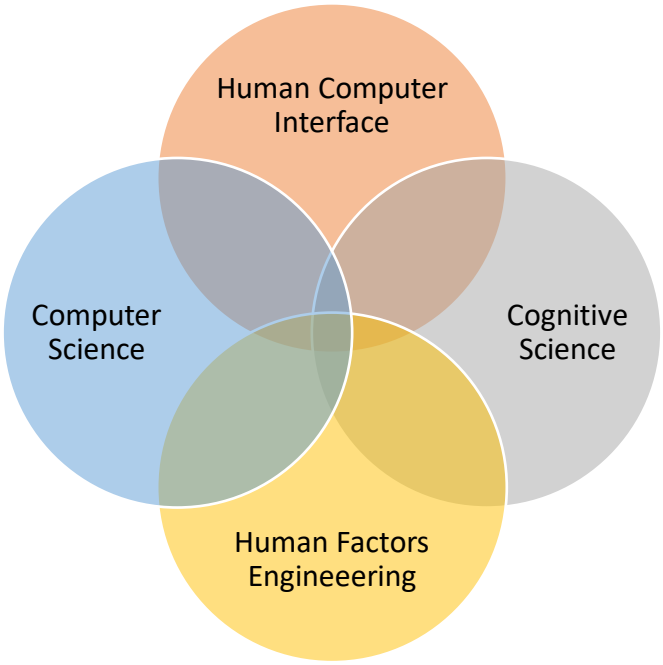
- Optimisations of data designs and database features
- Improved data flow between database objects and databases.

2.1.4 User-centred design, user experience and human-computer interaction in digital systems development

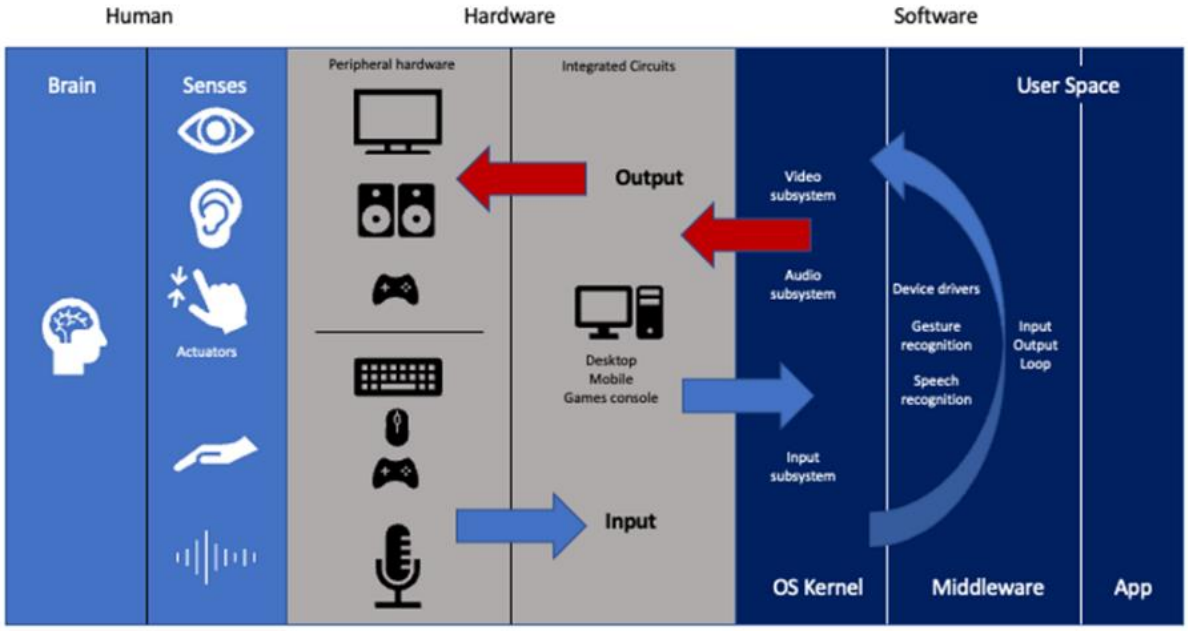
In this section learners will gain knowledge and understanding of the following:

- human-computer interaction
- User-Centred Design (UCD)
- Digital user experience (DUX).

Human-computer interaction

Specification amplification
Learners should understand: • human-computer interaction as a study of the User Interface (UI) between people and computers
Guidance
 Human-computer interaction (HCI) is a multidisciplinary field of study focusing on the design of computer technology and, in particular, the interaction between humans and computers. HCI surfaced in the 1980s with the advent of personal computing, when computers were no longer room-sized, expensive tools exclusively built for experts. From its origins, HCI would expand to incorporate multiple disciplines, such as computer science, cognitive science and human-factors engineering.

Specification amplification
Learners should understand: • interfaces and input methods
Guidance



Keyboard input: The most common way of entering data into a computer. An application or program needs to be running to accept the keystrokes made by the user at this stage in a computer's boot-up, for example. The user may be entering unprompted data, or the computer might have made a request for information.

Natural Language: This method involves speaking into a microphone connected to a computer's sound card. An application interprets the spoken word into digital data, which can be commands for the computer or direct files.

Touch: For many years touch was limited to using a finger to select items on devices such as public information kiosks or through-the-window selection screens at estate agents. But now tablet computers, smartphones and interactive desk surfaces are making sophisticated use of touch technology.

Movement: The joystick was the original movement device but more recently these devices can detect arm and leg movements directly without any need to hold a sensor in your hand e.g., Kinect, Xbox Kinect or PlayStation Move. These devices allow the computer to sense arm swings and other movements such as elbow and knee movements.

Pointer: A pointing device is mainly used to select items on the screen. A graphical user interface makes extensive use of the mouse as a pointing device. There are also other devices such as light pens which are also used as point-scoring devices. The classic pointing device for computer screens is the mouse, although there are many others.

Specification amplification
Learners should understand: • types and comparison of input method and user interface, and justification for their use in different circumstances
Guidance
Leaners should understand how input methods function and be able to suggest the most appropriate input method for the product under discussion e.g., a keyboard for writing an essay.

The best interfaces are almost invisible to the user. They avoid unnecessary elements and are clear in the language they use on labels and in messaging. Careful placement of items can help draw attention to the most important pieces of information and can aid scanning and readability. Always inform users of the location, actions, changes in state, or errors. The use of various UI elements to communicate status and next steps can reduce frustration for users.

Specification amplification

Learners should understand:

- social and health issues related to human-computer interaction and their impact when using the following:
  - mobile devices
  - desktop and laptop devices
  - peripheral devices
  - augmented reality and virtual reality devices
  - software applications

Guidance

Mobile devices:
Research has shown that people who use smartphones in excess may experience personal, social and workplace problems. People who identify themselves as "addicts" and "fanatics" exhibit signs that indicate depression, social isolation, social anxiety, shyness, impulsivity, and low self-esteem. "Technology addiction" refers to addictive behaviour related to social media, excessive texting, information overload, online shopping, gambling, video gaming, online pornography, and overall smartphone usage.

Desktop and laptop devices:
Working at a computer can cause back, neck and shoulder pains, headache, eyestrain and overuse injuries of the arms and hands. You can help avoid computer-related injuries with proper furniture, better posture, and good working habits.

Peripheral devices:
Issues associated with the use of e.g., toner in a printer, ozone generated by the printing process etc.

AR and VR devices:

- Motion sickness/nausea
- Headaches
- Isolation (spending too much time in the virtual rather than real world); and
- Being unaware of surroundings and potential dangers.

Software applications:
Apps have the potential to benefit consumers by offering interactive tools that help with treatment adherence and access to information. They can also pose safety risks if they are inaccurate and unreliable, mainly because consumers use them to make decisions about their health. There is a lack of consolidated evidence in this area.

Specification amplification

Learners should understand:

- methods of mitigating these issues.

Guidance

Digital Eye Strain
You can use the 20-20-20 rule to ease eye strain. Contributing factors are screen glare, bad lighting, and improper viewing distance. To follow this rule, try to take a 20-second break every 20 minutes to look at something that is 20 feet away.

Musculoskeletal problems
A small 2017 study found a clear association between self-reported addiction to smartphone use and neck problems. Overuse of technology can also lead to repetitive strain injuries of the fingers, thumbs, and wrists. If you are feeling the pain of technology, you can reduce these issues by taking frequent breaks.

Sleep
Having electronic devices in the bedroom places temptation at your fingertips, and it can make switching off more difficult. Exposure to blue light that devices emit can suppress melatonin and interrupt your circadian clock. These effects can make it harder to fall asleep and result in you being less alert in the morning

Emotional issues
Using social media can make you feel more connected to the world. But, comparing yourself to others can leave you feeling inadequate or left out. A recent study found that those with high social media use felt more socially isolated. The evidence suggests that social network use correlates with mental illness and well-being. If social media use makes you feel anxious or depressed, try cutting back to see if doing so makes a difference.

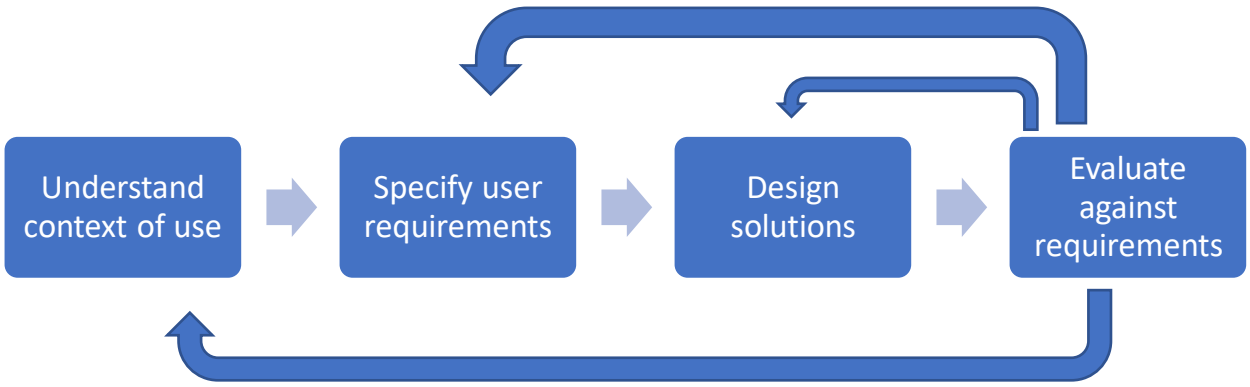
User-Centred Design (UCD)

Specification amplification

Learners should understand:

- user-centred design (UCD) in terms of an iterative process where designers focus on the users and their needs in each phase of the design process

Guidance



Specification amplification

Learners should understand:

- the purpose of UCD in terms of the product being designed to the needs of the user rather than the user having to adapt to the product

Guidance

In UCD, you base your projects upon an explicit understanding of the users, tasks, and environments. Your design team should include professionals from across multiple disciplines.

Experts may carry out evaluations of the produced designs, using design guidelines and criteria. However, you will need to involve the users in evaluation and ensure long-term monitoring of use.

Specification amplification

Learners should understand:

- the five principles within UCD:
  - a clear understanding of user and task requirements
  - incorporation of user feedback
  - active involvement of the user to evaluate the design of a product
  - integrating UCD with other development activities
  - an iterative design process

Guidance

If you change a product's design too late in the development process, it will cost ten times more than if you changed it during the requirements stage. Analysis and feedback are critical. The user-centred design makes sure that you design and develop products right from the beginning, exactly what your user wants.

Specification amplification

Learners should understand:

- the four phases within the UCD process:
  - specifying the context of use
  - specifying requirements
  - creating design solutions
  - evaluating designs

Guidance

Each iteration of the UCD approach involves four distinct phases. First, as designers working in teams, you specify the context in which users may use a system i.e., where. Then, identify and specify the users 'requirements. A design phase follows, in which the design team develops solutions. The team then proceeds to an evaluation phase. Assessing the outcomes of the evaluation against the users 'context and requirements, to check how well a design is performing. More specifically, how close it is to a level that matches the users 'specific context and satisfies all their relevant needs. From there, the team makes further iterations of these four phases and continues until the evaluation results are satisfactory.

Specification amplification

Learners should understand:

- how requirements are noted and refined through:
  - ethnographic study
  - continual feedback
  - contextual enquiry
  - prototype and usability testing

Guidance

Ethnographic study: A study through direct observation of users in their natural environment rather than in a lab. The objective of this type of research is to gain insights into how users interact with things in the natural environment.

Continual feedback: Refines through an iterative cycle of collecting feedback about aspects of the design and acting upon it.

Contextual inquiry: A type of ethnographic field study that involves in-depth observation and interviews of a small sample of users to gain a robust understanding of work practices and behaviours.

Prototype and Usability testing: Refers to evaluating a product or service by testing it with representative users using a prototyped system that has many but not all features of a fully

developed one. Usually, during a test, participants will try to complete typical tasks while observers watch, listen, and takes notes.
Specification amplification

Learners should understand:
• the use of tools used in UCD, including:
  • personas
  • scenarios
  • use cases

Guidance
Persona: A representation of a particular group of people with the same patterns; behaviour, needs, goals, skills, attitudes, etc. It helps you prioritise the design work, understanding what the user needs and what functions are simply nice to add and have. **Scenario**: It is a "daily life of" your target, of your persona. It is about problems the persona has. Here, small details both emotional and physical ones, matter. **Use case:** It is a series of steps for the persona to achieve the goal.
Specification amplification

Learners should understand:
• the main considerations of UCD:
  • visibility
  • accessibility
  • legibility
  • language.

Guidance
Visibility: Users should be able to see from the beginning what they can do with the product, what is it about, and how they can use it. **Accessibility**: Users should be able to find information easily and quickly. They should be offered various ways to find information for example call to action buttons, search option, menu, etc. **Legibility**: Text should be easy to read. **Language**: Short sentences are preferred here. The easier the phrase and the words, the better.

Digital User Experience (DUX)

Specification amplification

Learners should understand:
• Digital User Experience (DUX) in terms of:
  • design
  • navigability
  • performance
  • efficiency
  • cross-platform compatibility

Guidance
Design: This is about understanding the context of use, understanding what developers need to complete their tasks, underlying technology, and integration points, and focusing on how developers feel while using a product or service. **Navigability:** How systems are designed to be logical, sensible, and clear. **Performance:** Understand how application performance impacts a business. **Efficiency:** Measures the speed and how quickly users can accomplish tasks once they are familiar with the design of an interface. Think of it as the number of keystrokes or clicks it takes a user to complete a task.

Cross-platform compatibility: Ensuring each app runs, looks, and is performant across every available platform.

Specification amplification

Learners should understand:

- the scope of DUX from traditional online environments and apps, to more recent environments, such as:
  - wearables
  - virtual or augmented reality

Guidance

Wearables: People expect companies offering wearable technology and applications to demonstrate a higher standard of protection for their personal data. It is the digital user experience that health and wellbeing application providers are able to provide customers that will, to a large degree, determine the success of the whole wearable technology sector. Learners should consider all aspects of wearable technology from watches through clothes to augmented devices for sight and hearing.

VR and AR: have the potential to move into the mainstream. Immersive technologies are human-centred by design, meaning they have great potential to pack an emotional punch or provide practical support. Advances in technology make AR and VR user experiences more realistic and user-friendly. Learners should consider VR And AR experiences outside of gaming and the applications that are possible in medicine, retail, education, and day-to-day life.

Specification amplification

Learners should understand:

- the elements used when considering and evaluating DUX, including:
  - aesthetics of design
  - information architecture
  - accessibility
  - human computer interaction
  - ergonomics
  - utility
  - performance

Guidance

Aesthetics of design: Aesthetics are in all our senses, not just sight. Good-looking products and user interfaces are perceived as more valuable and have better qualities. Aesthetic design is a 4D experience. There are three important categories, which can make or break the aesthetics of designs vision, hearing and touch.

Information architecture: Aims at organising content so that users easily adjust to the functionality of the product and can find everything they need without a lot of effort. Information architecture has become a fundamental study in many spheres including design and software development.

Accessibility: Apps must be accessible to provide equal access and equal opportunity to people with diverse abilities. The UN Convention on the Rights of Persons with Disabilities recognises access to information and communications technologies as a basic human right. Accessibility supports social inclusion for people with disabilities as well as others, such as older people, people in rural areas, and people in developing countries.

Human Computer Interaction:

- **Anthropomorphic:** The anthropomorphic approach to human-computer interaction involves designing a user interface to possess human-like qualities. An interface may be designed to communicate with users in a human-to-human manner as if the computer

empathises with the user. Another example is the use of avatars in computer-based automation.

- **Cognitive**: The cognitive approach to human-computer interaction considers the abilities of the human brain and sensory perception in order to develop a user interface that will support the end user.
- **Empirical:** The empirical approach to HCI is useful for examining and comparing the usability of multiple conceptual designs. This testing may be done during pre-production by counterbalancing design concepts.

Ergonomics: Ergonomics is a science concerned with the 'fit' between people and their work. It puts people first, taking account of their capabilities and limitations. Ergonomics aims to make sure that tasks, equipment, information, and the environment fit each worker.

Utility: Usability and utility are defined as separate quantities: usability is the ease and efficiency of the interface apart from its function, and utility is the “usefulness” of its function.

Performance: From a user experience vantage point, identify and isolate service performance problems, speed up root cause determination and resolution and optimise digital transactions.

Specification amplification

Learners should understand:

- metrics used to test and evaluate the above elements, including:
  - task success rate
  - task completion time
  - retention rate
  - conversion rate
  - error rate
  - satisfaction
  - heuristic evaluation.

Guidance

Task success rate: It shows the percentage of participants that successfully complete a task and helps designers identify user experience issues. As long as tasks have clearly defined goals, success rates can be measured.

Task completion time: This metric measures the amount of time it takes a user to complete a task. Different users will have different completion times for the same task. In general, the less time a user spends on a task, the better the UX in an app or app-based website.

Retention rate: This is the percentage of users that continue to use a product over time.

Conversion rate: This measures the percentage of users who perform a desired action. Desired actions link to product goals and cover everything from completing a registration process to making a purchase.

Error rate: High error rates indicate usability problems. As with other UX metrics, it's crucial to define what erroneous actions are. The error rate is calculated by dividing the number of errors by the number of attempts made.

Satisfaction: This measures users ’overall fulfilment levels.

Heuristic evaluation: Heuristics are predefined usability principles (empirical rules of thumb, standards, and conventions) that have been observed and tested over an extended period of time. In a heuristic analysis, expert evaluators identify the usability issues of digital products and rate their severity.

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

In this section learners will gain knowledge and understanding of the following:

- types of social media
- functions of social media
- purpose and uses of social media
- impacts of social media use.

Types of social media

Specification amplification
Learners should understand social media in terms of digital platforms that permit the creation or sharing information via virtual communities.
Guidance
The term social media refers to a computer-based technology that facilitates the sharing of ideas, thoughts, and information through virtual networks and communities. Users engage with social media via a computer, tablet, or smartphone via web-based software or applications. While social media is ubiquitous in America and Europe, Asian countries like Indonesia lead the list of social media usage.
Specification amplification

Learners should be aware of:
• different types of social media, including:
  • social networking sites
  • media sharing networks
  • discussion networks
  • bookmarking and content curation
  • consumer review networks
  • blogging networks
  • social shopping networks
  • interest based social networks
  • anonymous social networks
  • merged social media and gaming

Guidance
Learners should be able to name and describe social media sites that conform to each of the different types.
Specification amplification
Learners should be aware of: • the main features and functionalities of these types of social media.
Guidance
Learners should be able to describe the main features of each of the above along with a description of how it is used.

Functions of social media

Specification amplification
Learners should be aware of the functions of different types of social media, including: • profile setting • status/wall posts • uploading media • messaging

• notifications • newsfeeds • comments/reactions • sharing • saving/bookmarking • privacy and security settings • integration with other social media platforms.
Guidance
Learners should be aware of the above functions and how they feature on each type of social media.

Purpose and uses of social media

Specification amplification
Learners should understand the purpose, and legal, ethical and professional implications of the different uses of social media by: • individuals • organisations.
Guidance
This would include, but not be limited to, various aspects of: • Data protection: The Data Protection Act 2018 and GDPR and how it relates to the identification of individuals and their data. • Libel: How e.g., sharing a post can be considered libel even if you were not the originator. • Trolling of individuals and companies by other individuals or companies. • Deliberate miscommunication and misrepresentation in order to gain an advantage as seen during Brexit and in recent election campaigns. • Social isolation and bullying. • Use of social media as a source of information about an individual e.g., using Facebook posts in order to judge a job applicant. • Paying 3rd parties to promote social media posts in order to promote a product, person, or idea whether that idea is negative or positive. • The power and pain that comes from having huge numbers of social media followers e.g., Beyonce has over 340 million followers whom she can communicate with directly, does she need to do press interviews? JK Rowling has suffered a lot of abuse, including death threats, as a result of comments she made about trans gender rights, her high number of followers worked against her in this instance.

Impacts of social media use

Specification amplification
Learners should understand the positive and negative impacts of the use of social media by individuals and organisations.
Guidance
Positive:

Social networking sites allow people to communicate and remain in contact with friends as well as meet new people. These sites allow people to find others with similar interests so that they can create a relationship with them and get to know one another. Groups can be joined or formed to meet people with similar interests, and views. Social networking allows for creative expression by using tools such as blogging and messaging to post ideas and stories.

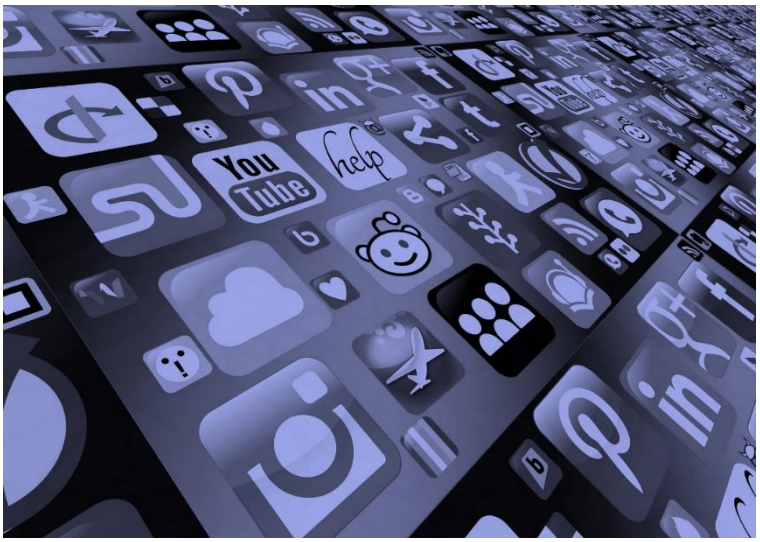
It is also used to discuss educational topics. Social networking is said to increase a person's quality of life and can reduce health risks. Many people report that they have not had any negative experiences with social networking, and schools are using it as an educational tool. The use of social networking helps improve the technological skills of students and exposes them to many diverse views about things. It also helps with communication skills and allows the learning of cultures from users all over the world.

Social media benefits businesses as well. These sites allow businesses to advertise and market services to a large audience. Numerous businesses have created profiles that provide detailed information about the business allowing it to advertise in a low-cost way. Businesses will gain more attention on social networks because their business profile is available to all users of the social network to see. Businesses like to use social networks to learn what potential employees are like and make decisions based on the information provided on the person's profile.

Social media is highly mobile and can be accessed through the use of various devices. People can use mobile phones to update their status, post comments, upload photos, send messages, and update profiles from just about anywhere.

Negative:

Social media reduces the amount of face-to-face socialising and replaces it with online interaction which is believed to result in low-quality relationships with other people. Teenagers in particular overshare information tin public that can hurt them in the future when trying to get a job, and deleting the information is not good enough as nothing dies on the Internet. Cyberbullying occurs as well, bullying people online in a public way which has had serious consequences including suicide and depression. People that frequently use online social networking are also prone to social isolation which can lead to depression and decreased social skills. A false sense of security leaves social networking site users vulnerable to security attacks such as hacking, leaking sensitive information, and sending viruses. Identity theft can also occur when a cybercriminal uses the network to gather personal information posted about people.



WJEC RESOURCES

Resources available on the WJEC website:	**WJEC GCE Digital Technology website**
	GCE Digital Technology Specification
	Sample Assessment Materials (online version)
	Sample Assessment Materials (paper version)
	Guidance for Teaching resources
WJEC Online Exam Review:	**WJEC OER website**

IMPORTANT DATES

First Teaching of GCE Digital Technology	September 2022
First Entries for AS Digital Technology	February 2023
First Examination for Unit 1 GCE Digital Technology	May/June 2023
First Submission of NEA for Unit 2 GCE Digital Technology	May 2023
First Entries for A Level Digital Technology	February 2024
First Examination for Unit 3 GCE Digital Technology	May/June 2024
First Submission of NEA for Unit 4 GCE Digital Technology	May 2024
First Resit for Unit 1 Digital Technology	May/June 2024
First Certification for AS Digital Technology	August 2023
First Resit for Unit 3 Digital Technology	May/June 2024
First Certification for A level Digital Technology	August 2024

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