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Theory of Knowledge

for the IB Diploma

3rd Edition

SUE BASTIAN
JULIAN KITCHING
RIC SIMS

Pearson

2.2 Knowledge and technology

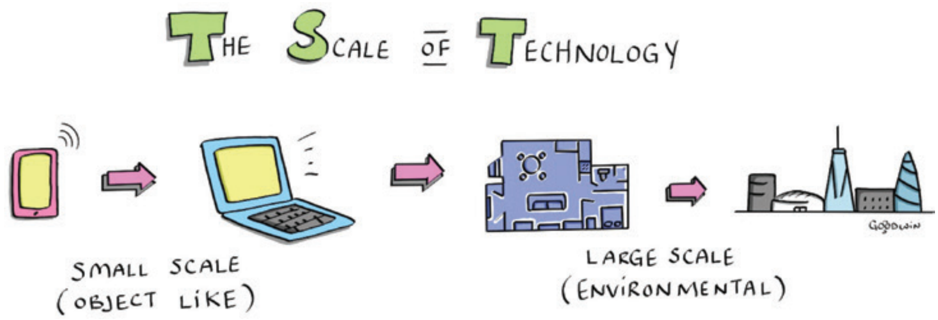
Introduction

The word 'technology', from the Greek stem *techne* meaning 'craft' or 'art', suggests a material product or process that has an impact on our everyday lives. Technology as an end-product is found in a work of art or a building. These are things that, in a direct manner, make a difference to the quality of life. But technology can also take part in a larger process of change. Consider a telescope or a harp. The telescope is instrumental in knowing about the heavens and the harp is part of a process of making music. They are means to an end rather than an end in themselves. Seen in this light, there are two strands to the intimate connection of knowledge and technology. Knowledge that we already have can be applied to solving the practical problems of life such as building somewhere to live. But, perhaps more interesting from a TOK point of view, technology often plays a central part in the process of making new knowledge. These strands are linked to make a dynamic circle – technology in the second sense helps to produce more knowledge that produces technology in the first sense and so on. We shall consider both strands in this chapter.

Let's build on these two aspects of technology. First, the word 'technology' names something physical in the world, such as phones and computers, that helps us navigate our way through everyday life. Such objects are relatively small in size and enable us to cope smoothly with the world. On a larger scale, technology can be found all around us in our material environment. Look around you now. You might be sitting in a classroom with geometrically ordered space, reached through ordered corridors with numbered doors. You might be in another type of building overlooking other buildings organised in a line along a street. You might be in a car travelling along a road with traffic-signs to help navigation. These are all examples of how human beings impose a vast amount of structure on their material environment in order to ease the cognitive effort of everyday life.

The second aspect is that technology is basically social. It is created and used within a social setting and, in many cases, the use itself originates in the social world. A mobile phone is not much use in a world such as that of *Le Petit Prince* where there is only one person. A car is not much use in a world where society has not built roads. In the main, the tasks that technology helps us to perform only make sense in a social setting – they are important and significant because they contribute in some way to living together. Technology is produced by society because of a social need and its use is regulated socially; that is, society confers value, meaning and significance to its use. Think again of the mobile phone as an example. There is more about this in the sections that follow.

Technology can be small-scale and object-like or it can be large-scale and environmental. Technology can also help with creating knowledge in the context of academic subjects – it can help with *knowing that*. But of primary importance in this chapter is the role of technology in helping us to solve the basic problems of living in society. In other words, in helping us with *knowing how* to live socially. The knowledge in this chapter is more to do with successful action in the world than about justifying true statements.



This chapter is structured according to the knowledge framework: scope, perspectives, methods and tools, and ethics.

- The section **Scope** examines in detail what could be meant by technology. Inspired by the TOK exhibition, we look at three objects that exemplify different aspects of technology.
- **Perspectives** examines the relationship between technology and the groups that use it and how technology shapes the perspectives of these groups.
- **Methods and tools** looks at technology as a tool for producing knowledge.
- **Ethics** examines the implications of technology in terms of the responsibility for knowledge and its use.

Scope

In the introduction, we took technology to be something material, either object-like or large and environmental, that enables us to do things in the world – including producing knowledge. In this section we explore the *scope* of Knowledge and technology as one of our optional themes. We do this by taking a close look at three objects that in their different ways make knowledge possible. Our starting point in this virtual exhibition is not the extraordinary achievement of modern digital technology but something with a history that goes back 3,500 years.

Technology is as old as human civilisation. Archaeology tells stories about the roles of natural materials such as stone, iron, and clay in shaping human knowledge. There is evidence of stone tools used by our hominin ancestors 3.4 million years ago. Clay is particularly useful because it is plastic when wet but rigid when dry. It has, of course, been used for millennia to make useful and decorative domestic things. The same qualities make it a suitable material for making digital technology – what we might these days call read only memory (ROM). When the clay is wet and soft, marks can be made on its surface. Later, after it has dried in the sun, it is hard and preserves the marks as a permanent record that can be read at a later date. Marking clay in this way makes it possible to store information over time and to move it from place to place. It reduces the burden on human memory: once the marks are made, humans can get on with other tasks but consult the exact details of the record when necessary. Therefore, clay tablets can be seen as an extension of human memory. The human brain, sometimes called ‘wetware’, can be supplemented with the tablet, ‘hardware’.

Virtual exhibition object 1

Figure 1 is an example of this technology and is the first object in our virtual exhibition. It is a sample from the Linear B tablets found in Knossos, dating from 1400 to 1200 BCE. The script is Mycenaean linear B script, comprising 89 syllabic signs and more than 100 ideograms (Malafouris, 2013, p. 68) that show numbers representing quantities of significant goods in and around the palace. The tablet in Figure 1 records numbers of bovine, pig, and deer hides to shoe and saddle-makers. The linear B tablets seem to function as an inventory of goods and labour.

Figure 1 3,500-year-old digital technology. An example of ROM in the form of the Mycaean tablets at Knossos.

The type of clay used dried rapidly and no additions or corrections could be made after the clay dried. This had implications for the size of the tablet. Large tablets would dry before all the information could be written on them, so the Mycenaeans used smaller tablets. These were arranged a bit like an old-fashioned card-index system in a library. Not only were the inscriptions significant but also the tablet’s position in the pile gave important information. The record-keeper filed them meticulously to be able to extract information quickly.

The use of space was also part of the storage and retrieval system. Just like modern files, each of the tablets had a standard format to aid information retrieval. The first word was inscribed in large signs, presumably to act as a sort of index for the filing system. This suggests that the tablets were physically arranged and manipulated by the records clerk. This is typical of the use of technology in a knowledge context. Physical objects do not merely hold information, they are manipulated in order to solve problems and answer questions. One way to think of this is that technology relieves the human mind of some of its burden. We can offload some problem-solving tasks to the environment itself. There are two necessary conditions for this offloading to take place:

- we need to produce the technology (that is, to structure the environment in the right way)
- we have to practise the use of the technology so that it becomes second nature.

Virtual exhibition object 2

Let's move forward in time by over 3,000 years to a mathematics class in a large school in the south-east of England in about 1973. At the back of a class, a 12-year-old boy is working hard on a calculation. In his hand is a plastic instrument that looks like Figure 2. It is called a slide rule.

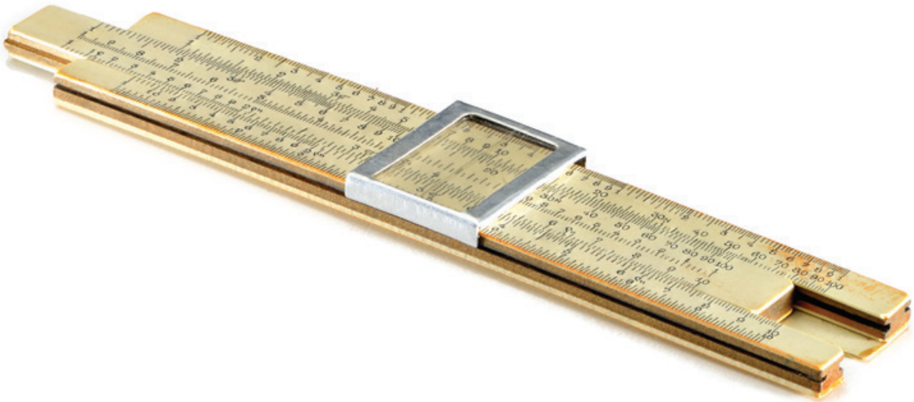


Figure 2 An ingenious piece of analogue technology from the 1970s: a slide rule.

A slide rule is essentially an analogue calculating machine. The tablets of Knossos are an example of digital technology because their meaning derives entirely from the symbols written on them. But a slide rule is analogue technology because the crucial feature is a physical distance between the symbols arranged to give the device its function. The carefully calibrated scales enable the operator to perform multiplication, division, powers, roots, logarithms, and trigonometric calculations to around three significant figure accuracy (but it cannot add or subtract). The boy in the maths class is solving trigonometry problems. He does not know it yet but in two years he will start using an amazing new invention called an electronic calculator. For the time being though, he is happy manipulating the plastic slide rule with his hands. In 1970s London, slide rules were everywhere: in schools and universities, in science labs, in the pockets of engineers and surveyors, on the bridges of ships, and in aircraft cockpits. The device had a cursor and sliding middle section which enabled the user to exploit the mathematical principle, $\log(ab) = \log(a) + \log(b)$ that numbers can be multiplied by adding their logarithms.

There are similarities between a slide rule and the Linear B tablets. The slide rule is a physical object that extends our human mental capabilities; the tablets are a sort of structured database. Just like the tablet file, the slide rule is manipulated by a skilled operator and relies on representations – marks that stand for something else. The marks on the tablet mean chariot wheels or swords; the marks on the slide rule stand for numbers. Just as the tablets extended human memory, the slide rule extended human calculating ability. In the Mycenaean case, the technology shaped the structure of society: there was a quite high social class of scribes or administrators who could read and write to the tablets. In 1970s England, there was a technically able class who could manipulate slide rules to solve certain knowledge problems encountered in the everyday world. In both societies, mastery of a technology led to social mobility.

Info box

Digital and analogue

You need to be aware of a distinction between **digital** and **analogue** technologies. Despite the familiarity of these terms, they are remarkably difficult to define precisely. This is largely because they are examples of questions of *representation* which still evade the best thinkers. Perhaps the best way to understand the distinction is to consider examples. The discrete 1s and 0s of computers and mobile phones are digital. The continuous voltage changes powering a loudspeaker are analogue. The discrete symbols of an English sentence (words and punctuation) are digital, while the depiction of a river on a map is analogue.

Virtual exhibition object 3

The third object in our virtual exhibition is a satellite navigation system for a car (Figure 3).

Figure 3 Satnav: digital technology from the 2000s. Outsourcing the taxi-driver's knowledge – but is it robust?

First, we need to consider a particular part of the world without Satnavs. Since 1865, London taxi drivers have had to take a test, described as the 'hardest exam in the world', in order to qualify for a licence to drive one of London's famous black cabs. They have to 'do the Knowledge'; that is, learn the exact street plan of the city within 6 miles (10 km) of Charing Cross. This involves learning 25,000 streets and how to drive them, the direction they run, one-way systems, dead-ends, where to enter and exit roundabouts. They also need to know everything on the streets: the location of all restaurants, pubs, shops, landmarks, flower-stands, laundromats, and so on, no matter how obscure. Examiners expect the would-be cabbie to know anywhere that a passenger might want to go. On average, it takes three years of full-time study to achieve the required standard. Trainee cabbies walk the streets on foot or use a motor scooter, usually devoting a day to a particular small area.

The Knowledge illustrates the construction of personal knowledge. It also highlights an important feature of technology: we embrace technology so readily because it allows us to access shared knowledge without the production of our own personal knowledge. The London cabbie must painstakingly construct knowledge of how to navigate London. In contrast, a rideshare app driver relying on GPS, has only to know how to operate the device that accesses the central system.

Of course, the difference between production and access raises questions about ownership and robustness. The London cabbie can be rightly said to own the knowledge that took three long years to achieve. This knowledge of the city is also personal: there will idiosyncratic features that belong only to the cabbie, certain details that enlivened the learning – a decoration here, the colour of a wall there, the smell of the river in Docklands. The rideshare app driver, on the other hand, has access to someone else's knowledge or knowledge that exists as part of a technological system, something centralised and standardised. This driver may have difficulty with non-standard requests like, 'take me to a Hawksmoor church' or 'take me to a fine example of early Victorian architecture'.

The London cabbie relies only on memory. The only thing that will affect performance is the gradual degradation of memory over time. The rideshare app driver, on the other

Info box

Robust

Knowledge is **robust** if it can withstand change. The London cabbie's knowledge is robust because short of a bad head injury or a missile attack on London the cabbie's knowledge can get a passenger from A to B. The rideshare app driver's knowledge of London depends critically on a complex system being in place and functioning correctly. If the system changes, the rideshare app driver may not be able to get a passenger from A to B. The rideshare app driver's knowledge is easier to come by but at the cost of robustness.

hand, is entirely dependent on the GPS system. If the satellite goes down, driver and passengers could be completely lost. On the plus side, the rideshare app driver did not have to undergo the hard work of learning the city, but on the minus side the accessed knowledge is dependent on others and lacks robustness.

These two knowledge systems illustrate some deeper questions about the differences between making knowledge and accessing it, about local knowledge and global or centralised knowledge, about ownership and power, and about how robust knowledge is when the system is disturbed. We examine some of these questions in the sections to come.

Things to think about

- To what extent do you think the tablets of Knossos allowed the Mycenaeans to extend their thinking capabilities? Can you come up with other examples of objects that extend our thinking capabilities? Do painters think with their brushes and musicians with their instruments? Do you ever think on paper by writing something down? Do you ever use mindmaps or other visual tools for thinking?
- In July 2019, a news item was published about a failure of the Galileo satellite navigation system that affects the GPS technology. This leads us to ask: How should we define robust knowledge? Is the cabbie's knowledge more robust than that of a rideshare app driver using Satnav? Is robustness a question of how many other people or how much technology is involved?
- For the Knossos tablets to function as part of the knowledge process, a number of other social practices had to be established. Try to think of three activities that people had to perform as part of the tablet record-keeping system. Then, consider the role of language and social hierarchy in making the system work.
- **Challenge** London taxi drivers are of interest to cognitive scientists and neurologists because the structure of their brain is somewhat different from the brain structure of non-cabbies. In particular, the taxi drivers have a bigger posterior hippocampus – an area of the brain known to be involved in spatial memory. This is an interesting case of a cultural phenomenon – learning the Knowledge changes neural structure and circuitry suggesting that the evolution of human thought processes is parallel to the evolution of culture (and is not driven primarily by genetics). Do you think this idea is plausible? Investigate this issue by checking out some of the sources at the end of the chapter). What are the implications if it is true?
- There are computer programs called 'expert systems' designed to diagnose illnesses from a description of symptoms. In some parts of the world (such as Scandinavia) these 'expert systems' are replacing the knowledge of human doctors. Does the 'expert system' have the same sort of knowledge as the doctor? A recent TV programme in Sweden pitted the skills of three doctors against three people who were experts in using the internet but were not medics. Each team had to diagnose the illnesses of real patients by asking them questions. The team of doctors won the competition convincingly. What are the implications of examples like these for 'expert systems'? What conclusions can we draw about the differences between human knowledge and machine intelligence?

Knowledge questions

- How has technology had an impact on collective memory and how knowledge is preserved?
- How does the use of technology shape the sort of knowledge we seek?
- To what extent is the internet changing what it means to know something?
- In what sense, if any, can a machine be said to know something?
- Does technology allow knowledge to reside outside of human knowers?
- Have technological developments had the greatest impact on what we know, how we know, or how we share knowledge?

Perspectives

This section develops the social aspect of technology – that is, that technology emerges from particular views of the world and also shapes those views. In TOK, the word ‘perspective’ is used to describe the point from which we view the world. It is a general feature of our whole outlook rather than a particular opinion or point of view on a specific topic. Two people may share perspectives but nonetheless disagree. Perspective is shaped by the network of concepts, practices, values, and norms that make sense within a particular culture. It is also shaped to an extent by our own history and biography, including our gender, religion, political affiliation, socio-economic status, and so on. We view the world from a particular point historically and culturally, and to a greater or lesser extent, our knowledge and our technology reflect this.

A word of warning here: it is tempting to think that because aspects of technology are social, it is somehow subjective or that ‘anything goes’. This does not follow. Technology has a social dimension – as does much of our knowledge – but that does not mean that it is radically subjective. Think back to the map metaphor (Chapter 1.1). Maps are the product of social factors such as the interests of the mapmaker and the purpose of the map. But maps are objective in that they are primarily about the territory, not the mapmaker. And as we all know, maps can be wrong.

The three objects discussed in the previous section illustrate the importance of the social aspect of technology. In each case, the object is situated within a framework of social practices and norms, without which it could neither function nor make sense. The tablets at Knossos played a role in an elaborate social structure that coordinated and controlled the demarcation of tasks and duties. Building wheels for chariots or textile production are highly specialised jobs performed by skilled craftsmen that need to be coordinated with other tasks and with the needs of the society as a whole. Moreover, the operators of the tablets were highly skilled in the ‘social technology’ of a sophisticated written language. Similarly, in the case of the slide rule, the use of the device required skill and a certain amount of physical dexterity. Its manipulation required technical mathematical knowledge and also a physical ability that was achieved by practice like mastering a craft, a sport, or a musical instrument. These practices were reinforced by schools and universities and regulated by clear norms and standards of correct usage. The same is true of the taxi driver who engages in a series of practices relevant to driving a taxi in the metropolis. Taxi-driving only makes sense in

Info box

Objective and subjective

Something is **objective** if it does not depend on the observer. It is an objective fact about the world that atoms are made up of electrons, protons and neutrons. It does not matter who is observing them, or if there is anyone around to observe them at all. The taste of honey is **subjective**: without a ‘subject’ there to do the tasting it doesn’t exist. There is a spectrum between these two extremes. A football referee might rule that a goal is scored. Hopefully there is an objective component to this. The ball actually crossed the line. However, the call did depend on the referee’s subjective perception of the ball crossing the line. There are objective and subjective elements to the call.

a particular kind of society – one with cities, roads, people who need to move around and, of course, an available mode of transport. In the case of the rideshare app driver reliant on GPS, society has arranged an elaborate physical infrastructure – satellites sending specific signals to be received by the GPS unit and converted into positional information. In all these cases, the use of the technology is regulated by an equally elaborate set of social structures; society adopts various methods for technology use and creates structures to support these methods.

These ideas have interesting implications, not least the idea that, as a social phenomenon, technology is also arguably an historical one. You can only understand the current state of a technology and the social practices it supports with reference to its historical background. The clay tablets *made sense* because of the history of the political and social organisation of the Mycenaeans, the history of their language, and the history of the social practices (such as chariot-making and textile manufacture) that the tablets coordinated. These histories flow together and converge in the technology of tablets. Similar histories can be cited in the case of the slide rule and GPS. Social history provided the need, and a history of knowledge production made the technology possible. Both streams of history are necessary. Even if Mycenaean civilisation had somehow mastered the mathematics of logarithms there would be no slide rules at Knossos because Mycenaean society did not require the sort of calculation that slide rules make possible. Similarly, in an imaginary society that lived underground, while it might have developed the knowledge to build a GPS system, the concept would not have made any sense given that it could never be used. The two historical strands, technology and culture, converge to ensure the emergence of a specific technology at a given time.

These strands might not be so easy to separate. It is completely conceivable that technology breeds technology: that a particular technological environment calls for the development of new technologies to service it. 20th-century Britain required the services of the slide rule because it was needed for engineering and scientific applications – in other words – other technology. The practices that were made possible by knowing how to operate a slide rule were involved in producing other technology such as buildings and machines. These would produce further new knowledge practices, and so on. A good example here is the Guggenheim Museum in Bilbao. The architect Frank Gehry has produced a strikingly innovative design for a building that houses an art collection. It creates a novel space that changes the way we view and reflect on the artworks displayed. Again, cultural knowledge and technology are intertwined. And if they are intertwined, so are their histories.

The intertwining of knowledge and technology has implications in terms of power. Technology empowers some groups – and disenfranchises others – through the knowledge required to produce it, control it, and operate it. Consider how technology divides society broadly into three different groups:

- the owners and controllers of technology
- the operators or technicians who have the specialist knowledge required to produce the technology, change it, and operate it
- a third group who are affected by the technology but do not have the technical knowledge to change it.

In the time of the Mycenaeans, the textile workers and chariot makers presumably belonged to the third group. While they were undoubtedly skilled craftsmen in their own domain, from the point of view of the tablet administration, they were the subjects of the system. The tablet operators were the civil servants and belonged to the second group. They were supervised, no doubt, by members of the first group who owned and controlled the technology. There are no prizes for guessing which social group had the higher social status (and whose knowledge was valued and taken seriously by society). The keepers of the tablets had control over the information encoded in them, in the sense that they, or their civil service bosses, could decide who else had access. The first two groups therefore acted as *gatekeepers* for this information. They had the skills to decode it and integrate it with other information to produce knowledge that had an immediate bearing on action. Day-to-day decisions regarding the running of the palace would depend on the entire knowledge system built from the tablets – 'more elm chariot wheels are needed because the stocks are running low – we need to ask the suppliers for more'.

Technology divides society into groups such as owners and controllers: those that have the specialist knowledge to produce or change technology and those who use it. It is entirely plausible that these groups tend to have different perspectives on technology and its relation to knowledge. These perspectives emerge when technology changes, as it inevitably does.

How does change affect the value of the knowledge held by each of the groups? The end-users – those who have little say in the technology being used – may welcome technological change especially if, like GPS, it makes everyday life easier. The first group of owners and controllers welcome the possibility of enhanced ownership and control offered by more advanced technology. But the middle group of technicians might be adversely affected. The value of their specialist knowledge is under threat and they might resist the introduction of new technology. The London cabbie belongs to this group. Doing the Knowledge is part of the tradition of taxi-driving. The instinct of many (if not all) cabbies is to resist the introduction of new GPS technology. One way of resisting is to argue for barriers to its introduction, perhaps by not licensing rideshare app drivers. Another is to devalue it by arguing that GPS means a reduction in the quality of service for the user group (passengers) because rideshare app drivers may not be able to give historical or architectural advice or information. On the other hand, a cab fitted with GPS can, if everything is working as it should, navigate to anywhere in London, possibly anywhere in the country or even the world.

Different technologies produce different expectations, different sets of norms and values, and ultimately different social practices. We can see the same pattern in the value of traditional knowledge in making textiles over the course of the industrial revolution or horsemanship skills after the introduction of the car. Technology empowers some groups and marginalises others. Changing technology alters this distribution of power, which in turn changes the value society places on knowledge held by different groups; this, of course, changes their power. The intertwining of technology and society is reflected in a parallel intertwining of technology and power. Could it be that conflicts such as the Luddite rebellion or the protests against the rideshare app are conflicts about whose knowledge is valued and ultimately about which group has power?

How might membership of these groups affect perspectives in relation to modern digital technologies? Most people are in the third group – they are the users of technologies. They do not own or control the companies that provide the services they use, nor are they able to change substantially what the technology does. End-users benefit from digital technology but only on the terms set by operators on behalf of owners and controllers. So how are these perspectives dependent on the technology they use? One view could be that it makes no difference to perspectives if one is a user rather than an owner. Surely, the great benefit of the internet is that it is egalitarian and makes information open to all, rendering the owner/operator/user distinction invisible. However, this view is increasingly difficult to defend. Search engines are designed on commercial principles rather than on principles that are friendly to balanced knowledge production. Newsfeeds are tailored to generate 'page hits' and so are likely to present content that is in keeping with the views of the user. People could end up seeing only one side of a current event based on their viewing choices. Analytic tools are reaching the point where the only advertisements that appear on the screen are for items related to existing personal interests. If a user supports one side of a political debate, the danger is that the online world acts as a sort of echo-chamber to reinforce prejudices and shield the user from contrary evidence and multiple viewpoints. There is plenty of evidence in the discussion about 'fake news'. This is the worrying bit: technology can create perspectives *of which the individual is not aware*.

Are we sure that these perspectives are brought about through technology and not through other things like human nature or interactions? Well, certainly technology plays a central role in the examples above. Google has an algorithm that determines the order of search results – which is likely to be based on commercial considerations rather than knowledge factors. What about social media technology? Does it create its own perspectives? What about ordinary human conversation – does it not produce a similar echo-chamber? What difference does the technology make?

Consider Twitter: it allows users a maximum of only 280 characters. What picture of the world can we have through such an abbreviated medium? Does that compression mean that we are pushed towards thoughts that can be expressed only within that limit? Are more subtle arguments that capture the essence of a complex world ruled out? Marshall McLuhan said more than 50 years ago: 'the medium is the message'. What are the implications for the perspectives from which we view the world if he was right?

Things to think about

- This discussion has centred on terms such as *knowledge, skill* and *information*. Take a moment to think about how these concepts fit together. Think of examples of information and knowledge from your own day-to-day life. Information, say, in a contact list, does not seem to be the same sort of thing as knowledge, say, in a science book, which does not seem to be the same as a skill like playing the piano.
- Why is it better to use library databases rather than Google when researching an extended essay? List three other ways in which digital technology changes the way we think about knowledge acquisition.
- What is the difference between contrasting perspectives with regard to technology and a difference of opinion? What is the difference between a perspective and a prejudice? How might this difference play out in terms of technology?
- Find out all you can about the concept of net neutrality. What are the implications of the challenges to net neutrality (in countries such as the USA) regarding the relationship between internet-based technology and knowledge?
- Investigate a political issue of interest in your local area. Are there different perspectives on the issue (rather than different points of view)? What role might technology play in establishing or maintaining such perspectives?
- Technology often provides metaphors for structuring our thinking when pursuing knowledge. The brain was likened by Leibniz to a mill, which in the 18th century was one of the most complicated things made by humankind. In the early 20th century the brain was thought to be like a telephone exchange. Now the metaphor is a digital computer. Can you think of other technological metaphors that we use to structure knowledge? What are the advantages and dangers of using such metaphors?
- The word-processing package used to write this chapter sometimes alters the style adopted and underlines certain phrases in red. The author is annoyed by these interventions but invariably takes their advice. To what extent does the programming of widely used applications shape our thinking or our knowledge? What are the implications in terms of power and diversity?
- Technology has shaped the way human beings live their lives. How have TV, Netflix, and computer games changed the way humans spend their leisure time? Is there any truth in the idea that technology has transformed the nature of leisure from 'doing things' to 'watching other people doing things'? What are the implications for knowledge if the only channel for staying informed about the world is TV news/news feeds/news websites/social media?

Knowledge questions

- How are online or virtual communities similar to and different from traditional communities of knowers?
- Do social networks reinforce our existing perspective rather than boost our engagement with diverse perspectives?
- What impact has the fact that English is the primary language of the internet had on knowledge-sharing?
- Is big data a radically new method of producing knowledge?
- How does the history of technology influence its current states?

Methods and tools

Technology can be used to produce knowledge. This section discusses the role of technology within the areas of knowledge and then extends these notions to knowledge outside an academic context.

Let's begin with the arts. Music is organised sound produced by physical instruments; visual art needs a medium that is altered by human design; dance is the organisation of the movement of physical bodies in time. The arts are to do with making material alterations to the world. As such, they are dependent on technology for their form and indeed their existence.

The aulos (Figure 4) is an ancient Greek example of arts technology. It consisted of two oboe-like tubes with reeds at one end stuck together. Each tube made its own sound, so the player could play a tune and an accompaniment at the same time. Each tube was controlled by one hand. The instrument was capable of producing five basic tones (but by blowing harder the player could probably achieve an upper octave). The two voices were not entirely independent because the player's breath controlled both tubes simultaneously. The double reed gave it an oboe-like quality. Thus, the sound of the instrument was determined by its particular physical arrangement. It defined the form of musical expression and its physical structure placed strict constraints on the sort of music that was possible. The instrument constrained the musical conventions that could be employed and therefore determined to a degree the whole art form.

Figure 4 Ancient Greek artistic technology: the aulos.

Now consider present-day musicians using computers. The music they produce reflects the tools they use – complex sounds that are literally unplayable on traditional instruments. This is reflected in the skill-set required – the manual dexterity of the traditional instrumentalist is replaced by the ability to work with and program complex computer packages. But musical creativity, talent, and a good ear are still required.

The history of painting gives other examples of technology defining the artform. Painters had to work with the available pigment technology. Changes in this technology produced changes in the art. Johannes Vermeer was famous for a shade of blue called *ultramarine* that was little seen in painting before his time because it was difficult to make and astonishingly expensive (Figure 5). Changes in technology made the production process easier. Arguably then, changes in technology produced changes in the nature of artistic knowledge – not just in terms of the skills needed to produce the art but also in terms of the nature of the work itself and the knowledge that it embodies.

Figure 5 Technology and the making of art: Johannes Vermeer's painting took advantage of a new technology for producing blue colour.

The use of technology in the sciences is often taken for granted. Science, as understood since the 1600s, is traditionally associated with technology in the form of instrumentation. Tycho Brahe's Astrolabe, Galileo's telescope and Hooke's microscope are usually described in science textbooks as instruments for extending human sense perception. But there is also science that depends on the existence of a particular instrument: spectroscopy relies on the spectroscope, X-ray and radio-astronomy rely on the appropriate detectors and radio telescopes. There are devices for creating very high- or very low-energy situations not usually encountered on Earth – for example, particle accelerators, vacuum chambers, deep refrigerators. There are also devices for bringing together and integrating a vast amount of data from disparate sources. Examples here include the computers that gather data from the detectors at the European Organization for Nuclear Research (CERN) and those that collated data from telescopes spread across the world to produce the first ever picture of a black hole (Figures 6 and 7). These machines and instruments play diverse roles in the production of scientific knowledge; roles that include data collection, data transfer, data analysis, and even automation of the experimental procedure itself. In some cases, technology is so central that it is tempting to ask what role human beings play and whether it is necessary to include a human element in scientific knowledge production at all.

Info box

Today, mention of CERN usually conjures pictures of the huge particle accelerator ring underneath an area straddling France and Switzerland, north-east of Geneva. It is a joint European project dating from the early 1950s with the aim of discovering what the universe is made of and how it works. It is usually associated with the large hadron collider (LHC) – a tunnel 100 m underground forming a circle 27 km in circumference. Elementary particles of matter (such as protons) are accelerated in magnetic fields to speeds approaching that of light and are then made to collide with other particles. The products of these collisions are detected by giant detectors and analysed by a sophisticated computer program. Over a long period, this accumulated data tells us about the fundamental constituents of matter in the universe, such as the Higgs boson discovered at CERN in 2012.

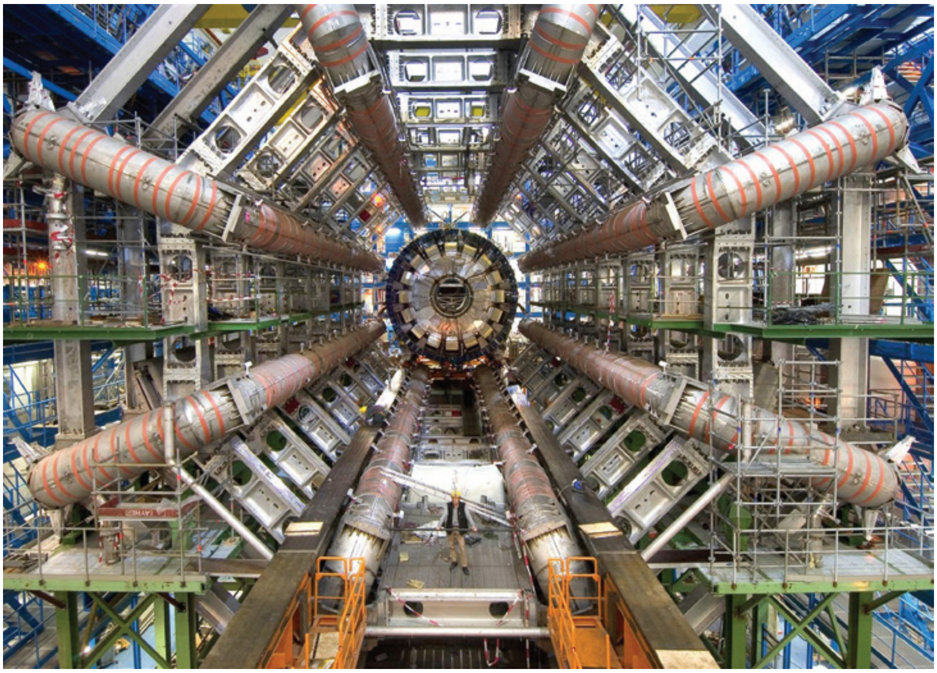


Figure 6 The Atlas detector at CERN.

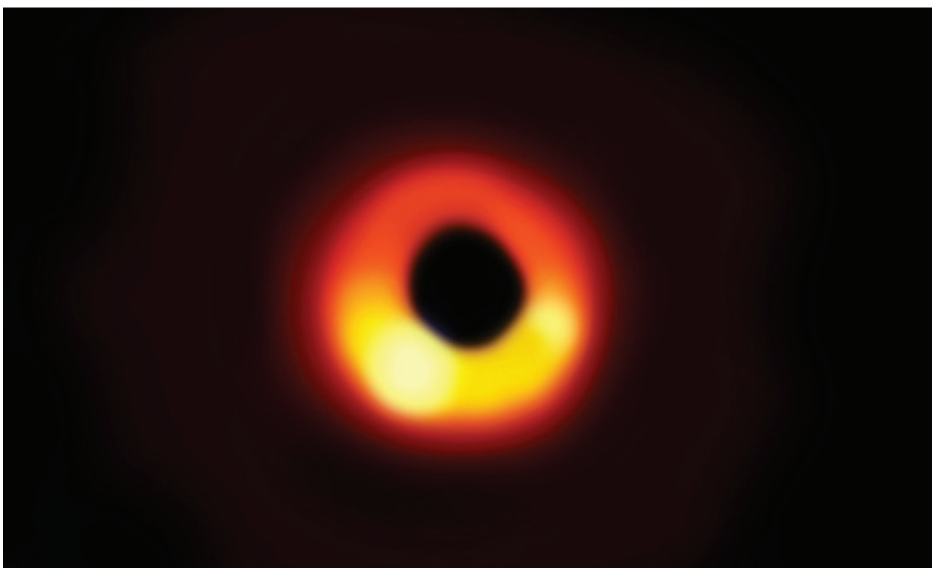
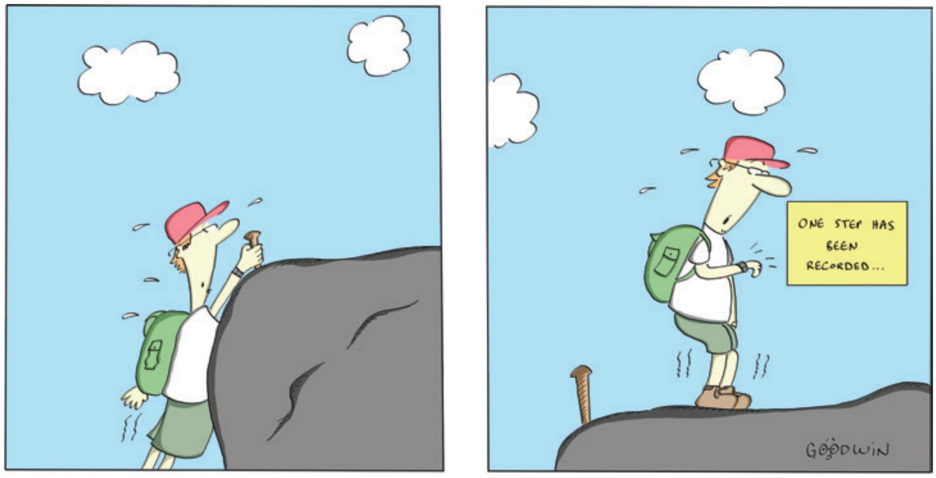


Figure 7 This picture of a black hole is not visible from any single telescope. It is compiled by putting together the data from the whole array and running a sophisticated computer program.

Technology has also transformed the way in which we gather evidence outside established areas of knowledge. CCTV plays a role in crime detection and prevention in many of our cities and when linked to digital facial recognition technology, it (controversially) allows security forces to gather data about our everyday activities. Such possibilities are inherent in smart devices such as speakers with voice-controlled assistants to respond to our every musical whim. These devices might also gather data about us that could be passed on to a third party. Our smartwatches can not only track our exact position but also make available information regarding our heartbeat and the nature of our physical activities; if this worries you, then think – so do smartphones! DNA technology is often used as evidence in criminal investigations and ensuing legal cases. Devices that give us detailed information about ourselves can also be used to give others that same information.



The use of technology in sport is also controversial. There are two main categories to this usage:

- helping to ensure fair play and good decision-making by the referee or umpire
- helping to gather data for teams to monitor performance of individuals and decide strategy.

Figure 8 In football, a VAR can be used to ensure fair play and good decision-making by the referee.

Examples of the former are the video assistant referee (VAR) in football, digital ball-tracking that is standard in international cricket, and electronic line judges such as Hawk-Eye in tennis.

Formula 1 motor racing is a sport that depends on technology for its existence. It is not surprising that it also employs technology for ensuring rule compliance, while in-car telemetry relays information relevant to team tactics such as which tyres to deploy and the timing of pit-stops. In professional basketball, each player's physical performance is micro-monitored in real time and integrated with statistical graphics regarding the progress of the game. This allows real-time tactical decisions to be made by the off-court team. The controversy surrounding aspects of the use of technology in sport stems from the same basic concern: is the 'magic of sport' diminished by an overly precise and rational scientific or engineering approach? In terms of the sporting performance, will it boil down to which team has the best algorithms? Has the knowledge of the referee or umpire been devalued, and that role changed from making judgement calls to something like a technician making scientific observations? Have actions in the sport been reduced to physics? If the answer is 'yes', does it matter?

As well as being a tool for producing knowledge in the first place, technology can also be a tool for storing knowledge and moving it from one place to another. We saw how the simple act of making marks on a clay tablet caused a revolution in knowledge making and sharing in Mycenaean times. Similar revolutions, though perhaps not so remarkable, have accompanied other technological advances in communications technology: the invention of papyrus, the printing press, and the internet. While the first innovation was a game changer, the later advances are, perhaps, important step changes. Yet what they all have in common is that they make shared knowledge possible and more widely available.

With the greater possibility of technology used for sharing knowledge comes the question of who gets to use this technology and who controls this use – who the *gatekeepers* are. There are groups of people who have privileged status regarding the technologies that support our own integrated knowledge systems. The owners of the physical internet, for example, have an ultimate say about which organisations may run their systems on it. The internet is owned by relatively few private companies with often unknown names such as Equinix, PAIX, MAE-East, DE-CIX, LINX, and AMS-IX. This is in contrast to the familiar networks that connect to an individual's systems such as Google, Facebook, Netflix, and Instagram. In the language of section 3, these are groups 1 and 2 – the owners and the operators. Shared knowledge requires technological infrastructure that is owned by someone and immediately raises questions about the way the infrastructure shapes the knowledge shared and about who is permitted to access this knowledge. We examine and develop this idea in the next section.

Things to think about

- Has the introduction of technology in science and art made it easier to do things that were done previously, or has it transformed the things that we do in these areas?
- Does it make sense to say that science is based on sense perception when observations are performed entirely by machines?
- The author of this chapter witnessed thousands of paper copies of scientific journals being pulped as part of a university library adopting an exclusively digital policy. One argument was that digital journals require less space and offer wider access. But it is not clear that online journals do offer wider access and there has been a recent campaign against the policies of journal publishers in their bid to further their business interests. What online resources can you access through your school library? Discuss the question of hard copy *vs* digital from the point of view of a user thinking about the *gatekeeper* question.
- Find out about the use of DNA evidence in criminal trials. The probability of a correct identification depends on which database is being used. The probability of mis-identification might surprise you. What problems are associated with using this technology in criminal trials? How could these problems be solved?
- Chimpanzees are known to use tools to solve problems (the famous example is using sticks to get at termites in their mounds). Tomasello (1999) describes how chimpanzees can learn to use tools by watching other chimpanzees. But it turns out that they learn from the changes in the environment rather than the deliberate action of the other animal. Human beings, on the other hand, seem to have a better grasp of intentional action: that the other person did something specific in order to achieve a particular goal (for example, using a tool with the intention of reaching the candy). To what extent do you think that it makes sense to talk about the relation of knowledge and technology of animals? How different is human knowledge from animal knowledge?
- **Challenge** Does thinking about technology expose a tension in the concept of shared knowledge? Shared knowledge could be thought of as individual knowledge that is the same as that of others – knowledge in common. But it can also be thought of as knowledge that is distributed across many people (and technologies) in such a manner that no one person has access to all of it. Which sense of 'shared' seems to fit best with knowledge in the modern world?

Knowledge questions

- How does technology extend or transform distinctively human mental capacities such as language use, abstract thinking, memory, communication, and problem-solving?
- To what extent are technologies like the microscope and telescope merely extensions to the human senses, such as sight or hearing? Or do such technologies introduce radically new ways of sensing the world?
- Is artificial intelligence, such as facial recognition software or the control systems in self-drive vehicles, restricted to processing information or can it also allow machines to acquire knowledge?
- How do the tools that we use shape the knowledge that we produce?

Ethics

Finally, we turn to the ethical dimension of knowledge and technology. Ethics here means questions about responsibility to oneself and others regarding the use of technology in connection with knowledge. By implication, this includes the long-term effects of the use of such technology. The previous sections have emphasised the power of technology to transform our lives through changing our fundamental relationship with knowledge. Technology changes how we produce knowledge and how we share it; it also changes our conception of what counts as knowledge and what we consider to be known or what can be known. Given that technology has such power, it is crucial that we think about the responsibilities accompany using it.

What responsibility do the producers, owners, and operators of technology bear to those of us using the technology? The idea of responsibility is familiar to students of TOK. It takes the form: person X bears a responsibility to Y by virtue of Z, where Z is a reason connecting X and Y. For example, the pilot of a plane bears a responsibility to the passengers by virtue of their official position as pilot and the trust passengers have in them because of this official position. Underlying this is a second issue of trust: the passengers trust that the airline company has ensured that the pilot has sufficient knowledge to fly the plane and the pilot trusts that the technology of the plane will do what is required of it. Questions that link responsibility to knowledge form the basis for the ethical part of the TOK course.

There are, of course, subsidiary questions linked to the production of knowledge in our example of a commercial flight. We trust that the engineers who designed and built the plane had the requisite knowledge of the physical principles of aeronautical engineering. These principles of aeronautical engineering are ultimately based on principles of physics. When we step into the plane, we are literally betting our lives on these principles. So, the responsibility for our safe air-travel rests not only on the pilot, the airline, and the engineers who applied the theoretical knowledge to a practical problem, but also on those who produced the theoretical knowledge in the first place. Responsibility is no longer a singular noun; there is a whole system of inter-related responsibilities at work and they are all based on relationships between different kinds of knowledge.

Figure 9 Can modern technology be programmed to make ethical decisions?

Modern technology takes this web of responsibility and adds a new twist. Human beings have responsibilities in carrying out everyday tasks such as driving a car along a public road. It therefore follows that a driverless car performing the same function must be expected to make the same 'ethical decisions'. A human car driver would have a responsibility for ensuring the safety of those in the car and other road users. This usually means adherence to traffic rules. This is great for automation – machines are good at following rules. There are occasions, however, when a driver might be expected to break a traffic rule in order to avoid a greater harm: for example, driving onto the pavement to let an ambulance through. There are also difficult situations where a driver must choose between the lesser of two evils: for example, to avoid hitting a child running into the road, a driver steers the car to one side and hits a dog. You can make up your own examples to think about here. Self-driving car technology must respond to this type of scenario. This suggests that the writers of the software would have to think about the ethics of the situation and make decisions about the set of preferences adopted in these cases. Since self-driving car technology follows a complex set of rules, the writers of the software would have to encode the rules for this type of moral problem into the software. Of course, this assumes that moral questions can be settled by a set of rules – which is itself up for debate. In any case, the programmers of the control system of the car suddenly have a new set of responsibilities because of the decisions they must make regarding how the car should react in critical cases. Technology raises new questions about the relationship between responsibility and knowledge.

The *gatekeeper* question discussed earlier is profoundly ethical in its nature if those denied access to a particular technology are thereby disadvantaged in some manner. In many situations, this is the case. The term 'digital divide' is often used to describe the difference between those people who have access to the internet and those who do not. Remember, we are not necessarily talking only about people living in remote areas far from internet provision. There is a debate in Sweden about the impact of internet technology on the lives of ordinary people. Over recent years, many physical branches of banks, station ticket offices, ticket offices in theatres, and cinemas have closed down as their services are transferred to the internet. An increasing number of shops no

Figure 10 Might physical ticket offices become a thing of the past?

longer accept cash. In a newspaper interview, Niklas Arvidsson of the Royal Technical University in Stockholm predicted that Sweden will be a largely cashless society by 2021. But there are many (predominantly older) people who do not use the internet and complain about being prevented from pursuing a normal active life. (Ironically, we are rapidly reaching the point where such complaints stop being recognised because local government and newspapers only accept electronic communications!) Technology changes the demand for knowledge for producers, operators, and users. It also comes with deep responsibilities.

Finally, what are the ethical implications of the notion that technology really does extend or supplement our perceptual and mental powers? According to some studies, blind people really do 'see' with their cane (Maravita and Iriki, 2004). Their body schema, the inner psychological map of the limits of their body, includes the cane. To deprive them of the cane is to deprive them of their means of seeing – it is tantamount to removing their eyes. If we accept that the mobile phone is an extension of our mental powers of memory, our ability to navigate, and our access to our social worlds, how ethically acceptable is it for the phone to be removed?

Things to think about

- How do we decide where the responsibilities lie regarding the knowledge invested in the following technologies?
  - self-driving cars
  - the possibility of enhancing human cognition through neural implants – also known as 'cyber-cognition'
  - the addictive effects of certain apps and games on their users
- Information and communications technology, generally known as social media, can be used to give people access to family and friends, and others with the same interests. It can also be used for online bullying. According to the website www.dosomething.org, 43 per cent of school-age children have been

bullied online, and in some cases bullying has led to death. What policy does your school adopt towards this problem? The problem is by no means restricted to school communities. Politicians, academics, and work colleagues have been subject to online 'pile-ons'. You might want to investigate the cases of Gina Miller, Kathleen Stock, Diane Abbott, and Rebecca Tuvel. Where does the responsibility lie in cases like these? What measures can be put in place to prevent online bullying?

- Find out about the Cambridge Analytica scandal. Where does the responsibility lie in questions about online interference with democratic processes?
- *Epistemic injustice* is the idea that the knowledge of some marginalised groups is not taken seriously. For example, epistemic injustice occurs in a meeting where male members do not listen when a female member is speaking. Discuss the ways in which the internet can be used to promote epistemic justice. Is there a danger that we build epistemic injustice into our digital technologies?
- Should internet speech such as posts to forums, social media contributions, tweets, and so on be more strictly regulated by hosts and moderators? Should contributions always be attributable to an identifiable author? Would this undermine key advantages of internet speech, such as the protection of anonymity for marginalised groups?
- What responsibilities do we have for the use of the data of others? Is it OK to put up a photograph of another person on Instagram, for example, without the subject's express permission? What are the implications of cases like this for data protection legislation?

Knowledge questions

- How might technology exacerbate or mitigate unequal access to knowledge?
- Does the existence of the deep web influence our view on whether or not some knowledge should remain secret or largely inaccessible?
- Should we hold people responsible for the applications of technologies they develop or create?
- On what criteria could we decide if activities such as 'hacktivism' are morally justified?
- To what extent have technological developments led to an increase in data being collected without people's consent or when they are unaware that it is being collected?

Conclusion

The dynamic intertwining of technology and knowledge runs like a unifying thread through this chapter. Wherever we look there is a loop: technology shapes knowledge and thereby shapes the structure of society itself, which in turn provides both the need for technology and the context of its development. In the broadest sense, technology and knowledge cannot be separated. They are two different aspects of something else – the self-organisation and self-sustainability of human culture. This is borne out by the virtual exhibition case studies: the Mycenaean tablets, the slide rule, and the GPS system.

In the larger picture, technology could be seen as transforming the nature of knowledge itself. In John Locke's time in the 17th century, knowledge was thought of as a personal possession – it seemed appropriate to speak of knowledge as a species of belief. In the 21st century, knowledge seems to be more like a possession of a group – it is distributed dramatically across vast distances and, with the help of large data stores, over time. Nowadays, it makes sense to think of knowledge as distributed across many people and things in the environment. These two notions of knowledge are in tension. It is difficult to think of the situation at CERN in terms of someone's beliefs. We need to adapt our understanding of knowledge to deal with the case where knowledge is distributed over people and things, and where knowing means not just believing but acting in harness with technology. And, as is often the case with actions, there are responsibilities too. But if knowledge itself is distributed across people and machines, how is responsibility distributed?

Oh, one more thing, but you knew this already, the young boy at the back of the classroom with the slide rule was the author of this chapter.

Exhibition thoughts

- There were three objects chosen in the **Scope** section to illustrate the idea that one way of thinking of technology is as something that extends human capabilities for knowledge through its physical manipulation. This is linked to IA prompt #23: *How important are material tools in the production or acquisition of knowledge?* What three objects would you choose in relation to the prompt? What are your reasons for choosing them? How do your objects answer the question in the prompt?
- The Linear B tablets can be thought of as part of the knowledge system of the Mycenaean civilisation. The knowledge that they made available was an integral part of the culture but also the culture made possible certain social practices that allowed the tablet system to work in the first place. This meant that the technology of the tablets and Mycenaean culture were intertwined. Think of another situation in which a technology produces knowledge useful to a culture, but also the culture develops in a way to make use of the technology possible. Choose three objects that make this argument for you. This is related to IA prompt #21: *What is the relationship between knowledge and culture?*
- It is easy to think of technology that serves the production of, say, scientific knowledge. In this question, think about the role technology plays in artistic and cultural terms. Choose a hobby: this could be a sport, art, craft, cooking, gardening, and so on. Choose three objects that show how technology has shaped knowledge in relation to your chosen hobby. Explain how your objects might help understand IA prompt #20: *What is the relation between personal experience and knowledge?*

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