

# Learning technology

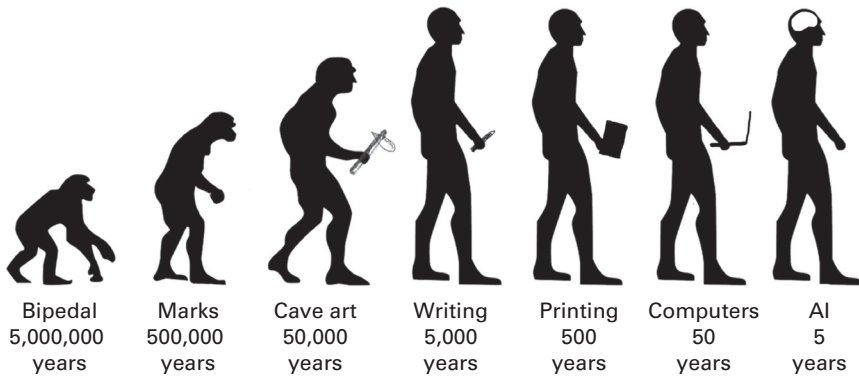
Learning technology is the most fundamental form of technology, the point of departure for all other designed technologies and cultural endeavours. It is the foundational technology that created all other technologies, as it underpins all cultural capital.

We need a deeper understanding of technology in terms of its history, the story of accelerating technological change. On the bedrock of several million years of cognitive development from bipedalism at around 5 million years ago, through a long era of stone tool use, we had the first meaningful marks at 500,000 years, the cognitive revolution and cave painting at around 50,000 years, writing around 5,000 years, printing 500 years, computers 50 years and AI at 5 years. This accelerating progress, with shorter and shorter periods of innovation and adoption, may well be the result of learning technologies' capability to speed up and spread teaching and learning.

This book is about more than history though, it is about this single idea – that learning technology has been the most important form of technology our species has created. The idea that learning technology has been a driver of cultural transmission and the success of our species is new and unexplored. For over 3 million years we have been creating tools and technology. We are *Homo technus* but behind all of this, we are the learning species and the most important technology, the one that underpins the invention and use of all others, is learning technology. From the stone technology that defined the cognitive capabilities of our hominid ancestors through cave paintings, writing, pencils, pens, alphabet, manuscripts, books, printing, computers, internet, AI and possibly neurotechnology and the Metaverse, this is a history of technology with a difference, one that looks at the technology that lies at the root of all our success.

We are distinguished, as a species, through our ability to create and use tools and technology. Other species, such as birds and primates, do use tools

FIGURE 1.1 History of learning technology



in a rare and limited fashion, but the first of our genus *Homo habilis* (handy man) through to *Homo sapiens* (knowing man) are by far the most successful of these competing species. We had better tools and technology and our ability to harness technology to help us learn is what allowed us to become the most successful species. This is the core idea behind this book.

This learning technology needs to be defined as fundamental to the progress of our species. It is the technology that precedes and enables the creation of all other technologies, as without learning, we have no cultural transmission and progress. It is important, therefore, to consider the science of technology – techn-ology – and lay out the ways in which technologies in this area evolved.

## Techn-ology

The study of technology is stuck somewhere between science and engineering. We need a renewed focus on techn-ology as a field of study, like psychology, biology or sociology, and a deeper understanding of its history and role in history. Our aim, therefore, is to look towards the science of technology, specifically learning technology, as identifying useful laws of technology. Not like laws of physics, but rules that emerge from the way we innovate, develop, use and perceive learning technology.

Technology has certain dynamics that have to be considered before one can understand the role it plays. It constantly disrupts long-established practices, which is why it naturally and predictably invokes strong opinions, even fierce resistance. The dialectic between technology and human affairs has always caused friction. Learning technology, in particular, is contentious and creates more friction than usual, as it lies at the heart of human development.

Learning technology is clearly a subset of technology. It is fitting, therefore, to start with a general definition of ‘technology’. This is not as easy as it sounds. Going back to the earliest technologies, stone tools, we need to say that technology is:

- found or made
- separate from the body
- changes the state of things, other organisms or ourselves
- is purposefully used with intentional cognitive goals.

Many books on technology start in the 18th century with the Industrial Revolution. Mumford’s *Technics and Civilization* (1934) was novel at the time, as it extended that time back to the monastic clocks of the 10th century, when monks needed to mark time with devotional prayers. His was the first systematic overview of technology as a force in the development of civilization. Mumford goes further in seeing the relationship between the inner cognitive world and the physical world of technology. It is in this tradition of the dialectic of mind and technology that this book falls. Technology over the last few million years has become more combinatorial, less proximate, more powerful and more autonomous. We evolved from *Homo habilis* into *Homo sapiens*, not in a linear fashion but through a complex process of migration, crossbreeding, genetic change and cultural transmission, starting with tool augmentations to our hands and bodies and eventually into the augmentation and extension of our minds.

Technology tends to be seen in purely mechanical and material terms. Most texts about technology, such as Usher’s *The History of Mechanical Invention* (1929) discuss technology as physical, tangible, mechanical devices, yet many of our most important advances have been intangible technologies, such as writing, alphabet, audio, images, video, software and different forms of media. So we must also include symbolic tools and technology, such as writing and software. The cognitive dimension is also fundamental to our definition. Technology is a social artefact, the result of cognitive effort and can be tangible or intangible, and in learning technology it is often both.

## Learning technology

That brings us to the question of what we mean by learning technology. The word technology comes from the Greek *Tekhne* (art, craft) and *logia* (writings),

something we can reflect upon as something that is used for learning. This brings us back to our definition above that it is found or made, separate from the body, changes the state of things, other organisms or ourselves and is purposefully used *to teach and/or learn* with intentional cognitive goals.

Note that learning technology need not be consciously used to teach and/or learn, one can be aware of that function or not, only that it is used for that function.

It can be technology that already exists, technology that is used unintentionally for learning, consumer technology co-opted and used for learning, technology that is designed specifically for learning, not just hardware but also software, even technology that learns for itself, such as AI. The scope of learning technology is wider than most imagine.

The key to understanding this interplay between ideas and technology has an underlying story around the generative power of teaching and learning. It was the role of technology in shaping cognition during the millions of years we used tools that necessitated teaching and learning. This was largely oral but eventually, around 5,000 years ago, writing emerged in societies with an agricultural surplus, the alphabet came later, then printing, broadcast media, computers, the internet and AI. These mediating technologies, when used for learning, are a necessary condition for all other significant technologies and what we know as cultural capital and civilization. They are the technologies that helped expand and improve the mind and therefore the march of progress. All technology is designed, and that design requires learning. Learning technology is therefore generative, the flywheel that allows ideas to be generated, communicated, passed on, acquired, archived, reused, discarded and improved upon. Each of these steps allowed civilization to scale and eventually envelop the entire globe. The cultural and economic consequences of technology are immense and the catalytic learning technologies that underlie this process worthy of study.

A usable definition of 'learning technology' must therefore include both hardware and software. Modern hardware invariably has, as an integral part of its function, input and output, software. Pens, pencils, erasers and paper are all hardware but have writing as their software. Manuscripts, codexes, printed books and papers are all hardware but have writing and images as software. Computers and their networks and even the cloud is

hardware, but the internet is also software, and the World Wide Web has every imaginable media type as its software, with code that controls the logic of delivery. In learning technology hardware is entwined with and inseparable from software.

## Technology and learning

Technology is the embodiment of our cultural achievements. It manifests and enhances our powers, physical and psychological. With our first hand-held axes, we used natural materials turned into tools, to hunt, survive, expand and thrive. We felled trees to create the energy for extracting and shaping metals into even more powerful tools. Tools begat more powerful tools. What is less known is the role that *learning* technologies have played in human progress.

There have been several stages in the invention and use of *learning* technologies: prehistoric cognitive development, writing, alphabet, printing, broadcast media, computing and internet, AI and data and now neurotechnology and the Metaverse. At key moments in our history, fundamental learning technologies were invented that unlocked massive cultural growth.

Writing was first invented in the advanced agricultural civilizations of Mesopotamia, Egypt and later China and Mesoamerica, and supported advanced economies and in those regions. The phonetic alphabet lies at the root of the advanced Greek, then Roman civilisations with their science, philosophy, poetry and drama. When there was little that was new in the way of learning technology, there was a hiatus – the scholasticism of the Dark Ages. Printing in Europe then gave rise to the Reformation and Scientific Revolution, Enlightenment and Industrial Revolution. Computers moved us into knowledge economies and the internet gives rise to the global online economy.

These learning technologies share some common rules of technology that determine their adoption, use and impact. These rules overlap with the general rules of technology but in some cases are specific to, or more relevant to, learning technology.

There are ten rules or premises for our inquiry. The first five major rules explain the ways in which learning technology has been and will be an increasingly important force in cultural progress; the second five are features of learning technology that specifically define its cognitive potency. As we progress with the story of learning technology, we shall see how these general rules have shaped not just learning but our entire cultural history.

- 1 Learning technology has cultural impact
- 2 Learning technology growth is exponential
- 3 Learning technology scales
- 4 Learning technology is combinatorial
- 5 Learning technology gets demoted
- 6 Learning technology is seen as real life
- 7 Learning technology extends cognition
- 8 Learning technology swings teaching to learning
- 9 Learning technology enables new pedagogies
- 10 Learning technology can be both good and bad

### *Learning technology has cultural impact*

There is a rich literature that reads history as being catapulted forward by innovations in technology, in economic cycles. No one has applied that logic to *learning* technologies. Our tool making had to be taught and learnt, writing and reading require detailed teaching and learning. This undoubtedly led to leaps in cultural and economic progress. The alphabet gave eastern Mediterranean culture a cardinal role in early science, philosophy and literature, particularly in Greece, a cultural source that remains strong in Western culture.

A lengthy aberration during the Dark Ages followed, when culture and progress were suspended because writing technology was stuck in manuscript production. These were written in Latin, a language of exclusion held in the hands of the few, namely the Church and monarchs. Nevertheless, manuscripts enabled cultural transmission across and through cultures, with even the works of classical Greece reaching us via Arabic culture and writing.

Western Christendom then flourished and by the twelfth century many cathedral schools had become universities. Places of study were not new and had existed in Ancient Greece and Muslim madrasas but the universities of for example, Bologna (1088), Paris (1150), Oxford (1167), Cambridge (1209), Padua (1222), Salamanca (1227), Prague (1347), Vienna (1367) and St Andrews (1410), while originally places for training the clergy, laid the foundations for the more secular institutions that now exist globally.

Teaching and learning then sprang into life with the advent of printing, its cultural impact being enormous. Printing put learning into the hands of anyone that could read, in their own language, and caused the Reformation

and Scientific Revolution that led to the Enlightenment. All of this resulted in an explosion of learning and learning institutions.

The Industrial Revolution began in Britain in the 18<sup>th</sup> century and by the mid-19<sup>th</sup> century it was clear that a literate labour force was becoming increasingly necessary. The rise of mass manufacturing had also led to a management class that needed to be trained. This led to the introduction of more widespread schooling and, to meet this demand, the mass production of pencils, pens, slates, paper, textbooks, notebooks and blackboards. These literally educated the masses, widening and increasing the cultural capital of the world.

Then came computers that sped up technological progress. They energized and accelerated the building of new knowledge economies. Hot on their tail came the internet, itself a research and learning network, which globalized learning resources through search, Wikipedia, YouTube and other services, as well as retail, finance and economics.

One can see how the underlying technologies of writing, printing, broadcast, computers and the internet have not just been technological revolutions but learning technology revolutions. It is hard to see how any of these wider technology and cultural revolutions could have taken place without learning technology being available. It is learning hardware and software that enabled human minds to build such political, economic and technological systems.

Finally, we are now in the era of artificial intelligence, or AI, the age of algorithms and data that promises to free up what Daniel Dennett calls 'pedagogical bottlenecks'. For the first time we have learning technology that doesn't just help us teach and learn – it can learn itself. Only now do we see that teaching and learning is not the sole domain of our species but a feature of our newly created technology – AI.

### *Learning technology growth is exponential*

Writing, printing, broadcast, computers, the internet and now AI, are all learning technologies that liberated exponential growth in knowledge and learning. Our ability to document, write, calculate, explain, plan, execute, teach and learn about what we normally think of as technology (mechanical, electrical, chemical and physical) has always relied on learning technologies that underlie their ideation. The great leaps forward in the history of our species have been leaps of the imagination, that envisioned technologies that would allow us to teach, learn and document our imaginative output, time after time, to further cultural transmission and development.

These leaps gave rise to science and advances in medicine, commerce, great art and every peak of human achievement.

Learning technology is not simply additive, it is a cultural and economic multiplier and one of the root causes of cultural paradigm shifts that is often categorized in terms of materials, namely stone, bronze, iron, water, steel, steam or silicon chips. Alternatively it is seen as mechanical devices: mills, ships, steam engines, looms, railways, automobiles, domestic devices, airplanes, rockets, satellites, computers, tablets and smartphones. But what lies beneath their development is teaching and *learning*, enabled by learning technologies. We mistakenly describe the more obvious visible and physical manifestations of technology when they are actually the effects or products of deeper and unrecognized learning technologies. Learning technologies progressively accelerate learning, compounding output and with each successive creation of learning technology, we get a shift in civilization.

Learning technology is still mostly ignored in favour of the obvious physical and mechanical categorization of technology. This fails to recognize that the history of technology has a deeper, hidden story of cognitive effort and progress that made this more obvious technology possible. Generative learning technologies lie beneath the physical manifestation of technology. These cognitive technologies allow the brain to create, document, manipulate and share ideas. 'At a few times in history, people have hit upon technologies that multiply, indeed exponentiate the growth of knowledge', said Stephen Pinker in *Enlightenment Now*. These learning technologies are inflection points in the history of our species.

This has been defined in economics as relatively modern periods of technological change, for example in Schumpeter's *Theories of Economic Development* (1911), with cycles of economic development driven by sudden changes in innovative technology. Carla Perez in *Technological Revolutions and Financial Capital* (2003) expands on the Schumpeterian idea to identify more fine-grained cycles of over-effusive investment and slumps, then periods of fruitful investment, resulting in significant improvements in productivity and economic progress.

To place learning technologies in context, we need to go back to our origins as a species. Learning technologies goes back to the origins of our stone tool-making species, which in a virtuous loop of cognitive development, allowed us to make several leaps.

## Learning technologies

More recently, it can be said that we overestimate technology in the short term and underestimate it in the long term.

### *Learning technology scales*

Scale matters but we often fail to address the real meaning of the word and the various species of scalability. Teachers are not scalable. Classrooms and lecture rooms are not scalable. When delivery is tied to both, it limits scalability. Tied to the tyranny of location and time, learning remains non-scalable.

Technology, by contrast, is intrinsically scalable. The ability to create and store writing gives it longevity and portability, the alphabet accelerates the efficacy of writing, printing duplicates writing and images, broadcasting reaches millions simultaneously, computers duplicate digitally, the internet duplicates globally and AI delivers personalization and created content. They all scale up successively in orders of magnitude.

There are four Laws that quantify raw scaling in technology: Sarnoff's Law, Moore's law, Metcalfe's Law and Reed's Law.

David Sarnoff had a long career in radio and television and was head of the Radio Corporation of America (RCA). His law defined the scalability of broadcast technology that sees the value of a broadcast network as proportional to the number of viewers. The advantage of broadcast technologies, such as radio and television, is their simultaneous transmission of learning to large public audiences.

In 1965, Gordon Moore saw that the number of transistors in an integrated circuit was doubling every year. He revised this in 1975 to doubling every two years. This meant that the processing power grew exponentially and that all the devices we now use doubled their processing power every two years while remaining affordable.

Metcalfe quantified the growth of value in networks. As the number of potential connections between nodes always outstrips the number of nodes, so connecting networks always create a value greater than the simple sum of the two networks, more accurately defined as the value of a network being proportional to the square of the number of connected users of the system  $n^2$ . This defines the scalability of computer networks and the internet.

Reed saw that the value of large 'social' networks scale exponentially rather than proportionally. Social use across networks is therefore behind the real growth of use on the internet. He defined this as a network with  $n$

members having  $2^n$  possible groups. There are cognitive limits to group formation, but this is still exponentially huge. In one sense it defines the learning power of a network – the potential connections, teaching and learning between brains on the network.

This explains the exponential scaling of learning technologies from one-to-many teaching, through the multiplier of printing, then the wide reach of broadcast media, the growth in power and functionality of computers and the massive exponential effect of the internet. In terms of the potential value for learning, it is linear for printing and broadcast networks, across a network with nodes it is squared and with social groups it is exponential. We shall see how this unfolded across the 20th into the 21st century.

Quite simply, as learning technology evolved, its scale and reach increased. With the invention of writing, we freed knowledge from the tyranny of space and time and were able to externalize our thoughts. Knowledge was captured, archived and distributed to many others in many different places, at many different times. Printing accelerated this same process, as identical copies could be mass produced and distributed nationally and internationally. This was scaled up again with broadcast media and went global and social with the internet.

Learning technology also scales in the sense that it is cumulative. Writing benefited from more efficient alphabet technology and then from more portable formats such as scrolls followed by books. Printing takes these technologies and duplicates exact copies in batches for distribution. Once digitized on computers, they also feed through digital capture, distribution and access.

Learning technology all comes together on the internet, with broadband, cloud services and streaming lessening the need for local storage. Most learning technology platforms are now cloud-based, and streaming has led to a renaissance of video and podcast learning. Access is available at anytime and anyplace on any device with an internet connection. The internet is a single, global source for storage and access, meaning that peripheral devices such as tablets, smartphones, audio devices, VR, AR and the Internet of Things can multiply its use. Most learning technology services are responsive in being smartphone ready. Ubiquitous smartphones allow access from almost anywhere on the planet.

Another dimension of scalability is personalization through AI and data-driven learning, where relevance can be scaled using personal and aggregated data. We have seen this with search, smart interfaces, knowledge bases, translation, transcription and globally delivered learning, such as Duolingo.

A new form of scalability in learning technology is machine and AI learning which allows software to learn and improve with use. This uses data, not just to train AI systems, but also to dynamically improve the systems as they are used. This is the scalability of Google search and translation. It is also true of learning systems such as Adaptive Platforms and Learning Experience Platforms.

The digital reformation has led to an age of digital abundance, the only real, scalable solution for ideas and content, as digital replication is possible at almost zero cost across the entire planet. From Gutenberg to Zuckerberg, scalability is the key to accessible, ubiquitous, low-cost learning.

### *Learning technology is combinatorial*

Combinations of technology are seen by Brian Arthur (2009) as the unrecognized driver of technological innovation. This is also true of learning technology. From writing instruments, inks and papyrus, parchments or paper, combinations of technologies have always been necessary. It is these, along with advances in technologies for reading, that make learning technologies fly.

Printing was not a single technology, it was the combination of presses, moveable metallic letters, ink, paper and binding that gave us printing, with copied texts being the replicable distributable entities.

Broadcast media is a complex combination of image and sound creation and capture, along with electromagnetic wave technology and the receiver technology of radios and televisions. There were many breakthroughs and applications in physics involved in the creation of this consumer and learning technology, with its immense reach.

The computer, with its combination of input device, processing unit, keyboard and printer, brought together a huge number of combinatorial possibilities.

A more intimate form of combination is between hardware and software. Learning technology almost always involves the combination of the tangible and physical (hardware) and intangible and psychological (software). Learning is, in essence, psychological, and learning technologies lead to relatively stable changes to long-term memory.

Combination also means cumulation. We see on the internet the cumulative delivery of all media types – text, images, audio, video, AR, VR – and

different forms of communications in different configurations. There is no technology that has been as combinational, cumulative and communicatively complex as the internet, with its network protocols for identification, transmission and presentation to a global audience for learning. It delivers a huge variety of options, including text via Wikipedia and other knowledge bases, video from YouTube and others, social media, podcast services for audio and many other free learning resources. Learning technologies have always been combinations of physical technologies, used to expand their breadth and depth, using all possible media. For example, immersive VR is a combined multimedia device, with stereoscopic vision, sensors, haptic gloves, bodysuits and treadmills brought together in the multiuser environment that is the Metaverse.

### *Learning technology gets demoted*

When defining the evolution of technology, it is almost compulsory to state Douglas Adams' (2013) wonderful description, and to be fair, his wording has not been bettered:

- 1 Everything that's already in the world when you're born is just normal;
- 2 Anything that gets invented between then and before you turn thirty is incredibly exciting and creative and with any luck you can make a career out of it;
- 3 Anything that gets invented after you're thirty is against the natural order of things and the beginning of the end of civilisation as we know it, until it's been around for about ten years when it gradually turns out to be alright really.

Technology is often a solution to a problem that has been forgotten. This is true of technology in general but particularly true of learning technology. We are born into a world of writing, pens, pencils, paper, printing, books, chalkboards and so on, seeing them not as technologies but just there in the background of everyday life. Learning through computers, smartphones and the internet falls into the category of being exciting and certainly something one can make a career out of. Artificial intelligence, data, neurotechnology and the Metaverse are, of course, the end of civilization as we know it! With learning technologies, we move like a wave, with old technology no longer seen as technology, contemporary stuff as exciting and leading edge, and future tech as an abomination. It was ever thus.

We therefore have to recognize that what we see as technology tends to fade and get declassified as technology or de-technologized. The technology

of the day quickly becomes the technology of yesteryear and eventually not really technology at all. This book attempts to save learning technology from that fate.

### *Learning technology is seen as real life*

Byron Reeves and Clifford Nass (1996) are two Stanford academics, who laid down some foundational research studies on media in learning. Their compelling case, backed up with empirical studies, showed that people confuse media with real life, a beneficial confusion as it is what makes movies, television, radio, video and online learning work. These 35 psychological studies all point towards the simple proposition that people react towards media socially even though, on reflection, they may believe it is not reasonable to do so. People think that computers are people.

There is no reason, therefore, why online learning experiences should be any less 'human' in feel than what we experience in the classroom. As long as media technology is consistent in its social and physical rules, we readily accept it. However, as Reeves and Nass found, when media technology fails to conform to these human expectations, we tend to reject the experience.

The spell is easily broken. We have a visceral response to awkward pauses and unnatural timing, so slight pauses, waits and unexpected events cause cognitive dissonance. Asynchrony, such as poor lip-synch or delays and poor quality of sound result in negative evaluations of the speaker and are problems that are cognitively disturbing and hamper learning.

Many modern theorists have begun to research different aspects of learning theory in relation to learning technology. From the actual physical use of technology in Papert and Harel's 'constructionism' (1991) to Norman (1998) and Nielsen's (1999) work on design and usability and Mayer and Clark's (2003) 500 + studies on what works in online learning, research has flourished in a slew of works on the cognitive interaction between technology and the mind.

### *Learning technology extends cognition*

Technologies often protected and extended our bodies (think of clothing, weapons and tools), while other technologies extend the mind (spectacles, pens, books, computers and digital voice assistants, for instance). The emergence of language began millions of years ago, writing came about thousands of years ago, printing arrived hundreds of years ago, broadcast media a

hundred or so years ago and now, in just a few decades computers, the internet and AI have appeared. We are now, especially with the advent of AI, seeing innovation in ‘cognitive’ technologies such as brain computer interfaces (BCIs).

We represent, replicate and scale our thoughts through cognitive technologies, such as speech, writing, alphabets, mathematics, audio, images, video, VR and other media. These external media allow our minds to directly create, express, manipulate and distribute our inner thoughts. From another perspective, they also allow our minds to listen, read, understand and learn. Pens, pencils, keyboards and touchscreens can be seen as extensions of consciousness, part of one’s mind and body.

But where does the mind stop and the rest of the world begin? Chalmers and Clark answer this fascinating question in *The Extended Mind* (1998). They see the components of learning technology as literally an extension of our consciousness, the very things we use to learn. These philosophers put forward the idea of extended consciousness or cognition as an alternative theory of consciousness.

Once written, a text is a piece of captured consciousness that can be read by others. To create this archived realm is to escape the tyranny of time and place. Written words can be read at any time in any place, as they are objects in themselves, separated from their creator. This is how learning happens and escapes from the consciousness of the human teacher. As a learner or teacher, learning technology extends and bridges minds in several possible dimensions. First and fundamentally, it changes long-term memory, which is the primary aim of learning. With that change we can recall and think about the past as retrieved history and create future possibilities. Our imagination is fuelled by this recall of knowledge and skills.

We can also escape the tyranny of location, to learn about and imagine places beyond our current location. Paper maps, then Google Maps and Street View and sat nav devices have become commonplace. Technology that extends the mind extends capabilities, foresight and creativity, allowing other forms of human capabilities and culture to develop.

### *Learning technology swings teaching to learning*

The history of learning technology is the history of technology becoming more accessible, scalable, frictionless, even invisible. A consequence of the scaling of learning technology is that it has gradually reduced the dependency on human teaching in learning. This process is now accelerating.

If we start with the hypothesis that cave paintings were social spaces where clans came together for learning, then we can see how one-to-one instruction, on say tool making and hunting, becomes a one-to-many teaching and learning experience. This drift towards one-to-many has been enabled by technology that reflected the mind of the teacher to a group of learners, and exponentially increased the ratio between teachers and available knowledge, as well as teachers and learners.

This is not to say that technology has or will replace teachers, only that the ratio has changed. With economic progress more countries have the ability to deliver more education and training but learning technology has allowed us to transcend the family, clan, classroom or lecture hall as units of educational transmission. Instead it is now increasingly online, borderless and global.

We spend only a fraction of our time in classrooms and in formal learning; most learning therefore no longer takes place in the presence of a teacher but in other contexts, often made possible by learning technology. We now search, read, write, watch videos, listen to podcasts, access the vast knowledge base on the internet, use smartphones and voice assistants, with increasing levels of sophistication. All of this is in the increasing absence of teachers, even other humans. We should not let formal 'schooling' blind us to this fact, as this is not where the majority of learning takes place.

Each successive innovation in learning technology changes the way we learn. Technology changes pedagogy, with the locus of learning shifting away from live, synchronous teaching to asynchronous learning. It is an uncomfortable truth for many but from the invention of writing onwards, the pendulum has always been swinging away from formal teaching to technology-based learning.

### *Learning technology enables new pedagogies*

McLuhan (1994) saw that technology shapes not only what we learn but how we learn. So learning technologies, both old and new, have all had a profound effect on the process of learning. Learning technology also brings with it an implied pedagogy. McLuhan's idea that technology shapes how we see and think about the world has accelerated and billions now search for knowledge and solutions through search engines such as Google and learn at a distance using technology. The printed encyclopedia was killed stone dead by Wikipedia; video has expanded as a learning medium and social media has exploded in popularity. Other forms of technology, such as

AI, BCI, the Metaverse and as yet unknown innovations will come in time. All of this has already had a profound influence on how we teach and learn and will continue to enhance the learning landscape.

New learning technologies create and enable new pedagogic techniques. The humble pencil and eraser allow one to fail, erase and retry as one learns. This is a simple example of technology enabling pedagogy. The chalkboard also allows the teacher to erase and rewrite when dealing with worked examples and is still popular in universities. With computer technology, the ability to cut, paste and edit all help one to write, while tools can be used to spell and grammar check, check for plagiarism and provide feedback on one's writing. We also have powerful search, research and citations at our fingertips, when only recently this meant browsing the shelves of libraries.

Allowing learners to do cognitively effortful, generative learning by writing on an internet-enabled computer and then distributing and publishing their work enables them to do things on their own in their own time and place. This is just one example of how a piece of technology can enable a range of pedagogic advances.

The internet creates more pedagogic opportunities since it frees delivery from time and place and enables the delivery of different media and complex interaction through scenario-based learning, simulation and gamification, to name but a few. Flight and medical simulators, for example, are clear examples of technologies creating sophisticated pedagogic options for pilot and physician training. The free live video communications that flourished during the Covid-19 pandemic are another example of pedagogy being enabled by technology.

AI and data-driven systems allow pedagogic techniques like personalization through adaptive learning, delivering to the right person, the right experience at the right time. There is also the algorithmic delivery of deliberate practice, spaced practice and motivational pedagogies such as behavioural, nudge learning. An enormous set of pedagogic options can be blended into an optimal blend suited to specific groups of learners and types of learning. This is not just about learning delivered solely through technology. Offline learning can also be designed, delivered and managed through technology.

*Learning technology can be both good and bad*

The pen is said to be mightier than the sword but most technology, including learning technology, has an ethical dimension. With learning technology,

these ethical issues are fairly minor compared to say weapons of war, the use of fossil fuels, even driving cars. We continue to drive cars despite the fact that nearly 1.5 million people die every year in car crashes, with the number injured even higher. This is a casualty number larger than that of an annual world war. Plastic syringes may save lives, but plastic is killing our oceans.

Learning technologies have no lethal consequences but there are still downsides. In printing, paper production means felling trees and is one of the most polluting manufacturing processes ever invented. Billions of plastic bricks have been produced by the famous Danish toymaker, yet single-use plastic is a menace. The internet and AI have created ethical issues in social behaviour, crime and politics. Astonishingly, even the humble learning management system has had a genocidal consequence. In 1939, Tom Watson, CEO of IBM, flew to meet Hitler and sold him a punch-card called the Hollerith system. As we shall see later, it stored data on skills, race and sexual orientation, and was subsequently used to select people for slave labour and the death trains to concentration camps.

At a more prosaic level, although some learning technology in schools, universities and the workplace is admirable, it also is not without ethical problems. Learning technology can be used for good, for example, as assistive technology for those with physical or psychological problems and during the Covid-19 pandemic when there was no alternative. However, some argue that its use increases social inequalities by ignoring the digital divide, being selective and elitist and using time and money that would be better spent elsewhere. This seems to be an eternal problem with technology and learning technology, its Janus-face as a force for both good and bad.

## Dialectic of learning and technology

Learning theory has always been the product of the larger cultural milieu it finds itself in and that is both productive and limiting. So what has 2,500 years of learning theory and practice taught us? Firstly it has been remarkably compliant to religious, philosophical and political movements and shifts. It not only bends with these winds, but it also hangs on to them, long after their real effect on society has waned. In a sense, the learning landscape reflects the past more than the present or future. Old theories and practices get locked in, often through institutional inertia. Education and training can be slow to learn.

The lecture today is not that different from those delivered at Plato's Academy 2,500 years ago. Even when new theories and practices are adopted, such as learning styles, they can be faddish and ill-researched. Technology is always ahead of sociology and even in education, the technology and associated pedagogies used by learners tends to leap ahead of their teachers and institutions. Almost all learners with access to internet technology are, to some degree, online learners.

We learn over a lifetime, yet the focus is largely on schooling. Schooling remains a stable offering, with standardized curricula, tests and teaching the norm. Most learning theorists have focused on formal learning along with taxonomies of learning and defined instructional models. Yet little of our learning across a lifetime is formal. Apart from one major bout of formal schooling between the age of 5 and one's teens or early twenties, the rest is largely informal. Pre-school is almost wholly informal, and, in the workplace, research consistently shows that the great majority of learning is informal.

A common refrain from educators is that this is not about technology but learning. So was it learning then technology or technology then learning? This idea is flawed as the relationship between the two is a complex dialectic. The technologies that shaped the learning landscape were writing, alphabets, writing instruments, books, broadcast media, computers and the internet, yet none of this technology came from the 'learning' community. The technology came first, its use in learning second. What did come from the learning community was the technology of the lecture hall and schoolroom, such as lecterns and blackboards. However, a lot of learning technology has been shaped by learning professionals who make it usable and productive. It has been a *dialectic* with constant cross-pollination.

The real world of learning is messy, a combination of formal and informal learning. We are a nurturing species and child development is an intense learning experience but not one that is especially formal – parenting is not teaching. We then nurture through a legally enforced period of schooling and many now continue with formal learning beyond school. Of course, it does not stop there, as beyond formal schooling is work and life. Workplace learning is mostly incidental and unintentional. In life itself, we often learn for pleasure. It is not so much lifelong learning but a life of constant formal and informal learning.

Learning technology does not only exist in the structured world of educational institutions and organizational training. The real world creates lots of consumer technology that is useful outside of these environments. Just

because it is not seen in the classroom or lecture hall does not mean it is not used in learning. After formal education most adult learners become fairly autonomous. In some cases learning technology emerges, without reference to learning, yet has a profound pedagogic effect on the way people learn. Google is a good example. It changed the way we access knowledge, find academic papers, do research and solve problems when learning or at work. This irreversibly changed the way we learn. Wikipedia, a crowd-sourced knowledge base, was also a major leap forward in terms of the way knowledge could now be dynamically created, edited, discussed, distributed and accessed. YouTube has become a learning platform, accessed by huge numbers of formal and informal learners, where 'how to' learning is globally accessible. Many MOOCs, Khan Academy, Duolingo and other services came not from within education but from outsiders who shaped the learning landscape through innovation.

There are many examples of technology that are sensitive to learning theory and learner needs. All manner of useful content creation and delivery, communication, collaboration, assessment, learner management, learning management, simulation, spaced practice and adaptive, personalized systems have been developed with learning in mind, often by educators. Moodle and open educational resources (OER) are good examples. Moodle, built by Martin Dougiamas, created an open source system used by educators around the world.

Culture, in the short term, tends to trump technology, until that technology is assimilated into culture, where it often drives that cultural norm. Institutional inertia needs to be overcome for technology to succeed. Learners often use learning technology that is not provided by or even approved by their organization. All sides produce friction when they stick to their prejudices. The learning technology side when they overreach and overpromise, the learning side when they refuse to consider change and overreact.

We have seen the disastrous consequences when both tech and teachers get obsessed with 'devices' leading to the wrong focus on short-lived 'mosquito projects', when what is needed are 'turtle projects' – slower but long-lived – leading to sustainable change. It sometimes leads to the procurement of tech that is expensive and poorly implemented with a lack of support for teachers. Writing was by no means popular when learning theory was discussed by Socrates and Plato. Printing was seen by many as the Devil's work. Broadcast media were seen as a cultural evil. In the computer age, the internet, social media, smartphones, Wikipedia and AI

have all come under heavy fire. Every learning technology revolution has been dismissed as irrelevant and harmful but eventually turns out to be useful and often essential in learning.

Compromises are often struck. Blended learning is a good example, something almost everyone on the technology sides agrees with, but it remains difficult to implement because of the technology versus teaching wars referred to above. Blended learning proposes the use of both offline and online, classroom and internet, and is designed to optimise learning opportunities and experiences. Learning is a process not an event, and freeing it from the tyranny of time and place will continue to be beneficial for learners.

In practice, it is a complex dialectic. Over millennia, technology has played an increasing role in teaching, and more importantly, learning. The teachers versus technology argument is specious because it fails to recognise that learning has always been an accommodation between the two. Technology evangelists can overplay their hands with excessive, even egregious claims and marketing, while educators can also overplay their hands, putting up resistance where CAVE (Colleagues Against Absolutely Everything) dwellers defend the traditional against any form of change. Both sides have their purists but most eventually see this as a synthesis.

Even when they work together, applying new technology to old thinking doesn't always result in progress. The simple transfer of books to screen, theatre to cinema, lectures to online and so on, is not optimal. A new synthesis, often blended learning, sometimes a radical shift, is almost always better.

Far from being a 'black box', something separate from us, learning technology has profoundly shaped our evolution, progress and culture – it will shape our future even more, as we increasingly depend on being smarter to survive. This complex dance between ourselves and technology is far more multifaceted than the simplistic trope, 'it's about people not technology'.

## Technology matters

There is a much bigger historical and philosophical story around technology here that is worth laying out before we take our deep dive into learning technology. Plato's articulation of the philosophy of technology in his *Timaeus*, as the work of an 'artisan', sees the universe as a created entity, a technology. Aristotle is less metaphysical and makes the subtler observation in his *Physics*, that technology not only mimics nature but continues 'what

nature cannot bring to a finish', a good description of both learning and technology. Both set in train an idea that the universe is *made* by a *maker*, the universe as a technological creation.

What followed was a 2,000-year history of Western culture that still believed that the universe was a creation. William Paley, in his formulation of the argument for the existence of God from design, used a technological analogy, the watch, to prove the existence of a designed universe and therefore a designer, called God. In *Natural Theology or, Evidences of the Existence and Attributes of the Deity* (1829), Paley used the argument from analogy to compare the workings of a watch with the movements of the planets in the solar system and concluded that it showed signs of design and that there must therefore be a designer. God as technologist and watchmaker has been the dominant philosophical belief for two millennia. Richard Dawkins cleverly titled his book *The Blind Watchmaker* as a counterpoint. Modern Paleys, and there are many, have resurrected his watch argument, notably in the Pennsylvania school district trial in 2004, where the expert witness on both sides used the watchmaker argument to present their case for and against 'intelligent design'.

Technology clearly helped generate this metaphysical split, this binary separation of the subject from object, that allowed us to create these new realms, both real and apparent. Technological progress has always invoked both utopian and dystopian visions and as learning technologies are close to the developing minds of children, they are seen as particularly suspect.

The farming cultures in the fertile crescent of the Middle East, using the spade, plough and scythe, had time to reflect on the back of their technology-aided labour. If technology fuels ideas, learning technology fuels the dissemination of ideas. Interestingly our first written records, on that wonderfully permanent piece of technology, the clay tablet, are largely the accounts of agricultural produce and commerce. At heart, we are accountants, with our great religious books of accounts, the first global best sellers, holding us to account for our sins.

Learning technology has not, historically, been seen as dystopian, yet when it starts to put power in the hands of the learner or free us from the tyranny of the teacher, with computers and the internet, the dystopian visions become a flood. When we invent technology that learns by itself, AI, the dystopian visions almost give way to hysteria.

The learning technology that was writing may have suggested, then created God, but in the end, it slew him. The very technologies, writing and books which captured these beliefs and fuelled the evangelical spread led to

the invention of the printing press, which in turn promoted the learning culture that rejected religious hegemony. Printing, with its rapid duplication of religious texts was seen as spreading the word but soon all sorts of alternative worldviews emerged.

Copernicus, drawing upon printed, technology-generated data and mathematics, displaced us from being at the centre of the universe; we ended up not even being at the centre of our own little twirl of planets. Printing continued, fuelling science until Darwin destroyed that last conceit, that we were unique as a species and created by the hand of God. Now the product of the blind watchmaker, double-helix and genetically encoded algorithms, not a maker but reduced to mere accidents of genetics, the sons and daughters of genetic mutations and variability.

We were suddenly adrift, anchors lost but we had learnt to be a cunning species. We make things up, but we also make things and make things happen. Our new solace was not from being created forms but by creating technology ourselves.. We scaled agricultural production through technology in the agricultural revolution and then abandoned the fields for the factories. We then created technology that scaled factory production in the Industrial Revolution and went on to scale mass production in the consumer revolution. We have even learnt, with AI and data, to make machines that can know and think on our behalf. Technology literally shapes our conception of ourselves.

René Descartes, as a dualist, thought of mind and body as separate. Although failing to explain how one causally interacts with the other, he did see the physiology of the body as a machine and in this context we began to see 17<sup>th</sup>-century robots, such as Jacques Vaucanson's 1738 flautist, that astonishes even now. But it was Leibniz who was the true progenitor of AI, with his theory that language mirrors thought, and a universal language may be written that manipulates symbols representing concepts and ideas using logic to simulate reasoning. This is to see the mind in terms of a computational model. He was precise on this idea as, in 1666, he quoted Hobbes as having proposed the same theory, 'Thomas Hobbes, everywhere a profound examiner of principles, rightly stated that everything done by our mind is a computation'. Note also that Descartes and Leibniz made significant contributions to algebra, geometry and calculus, influencing AI in other, more purely mathematical ways.

AI has suddenly made the dialectic between man and machine a lot more complex. Martin Heidegger said, 'Only a God can save us'. What did he mean by this? That technology has become something greater than us,

something we now find difficult to even see, as its intangible hand has become ever more invisible. It now teaches us, and we learn from it. We must reflect on this technology, not as something separate from us, but as being of us. We must face up to our own future as makers of technologies that in turn make us.

The postscript is that artificial intelligence and neurotechnologies may, in the end, be the way forward, with learning technology that makes us better learners, augmenting our intelligence. AI may be better explained as augmented intelligence. In the same way that the brain has limits on its ability to play chess or GO, it may also have limits on the application of reason and logic. AI that teaches us to learn may be the God that saves us from ourselves.

## Conclusion

These are the major questions this book addresses, with a focus on learning technologies. We track learning technologies over the entire period of their existence, looking at how they enhance and amplify learning. Sometimes they push other technologies out, making them obsolete, such as scrolls, manuscripts, videotapes and the printed encyclopedia. Sometimes technologies from the past are resurrected and given a new life, such as out-of-print books now digitized and made available on the web. Sometimes older media is used in radically new ways, such as video and stereoscopic vision in VR.

Online learning technology enhances, increases and amplifies knowledge and learning globally. The history of learning technology shows that, in general, it democratizes, decentralizes and disintermediates the learning game. Personal computers and the internet have been the real source of pedagogic change over the last 25 or so years and are something that has changed the behaviours of learners, independently of teachers, teaching and education.

What is notable about many of these breakthrough learning technologies is that they came from outside of the orthodox system. All have changed how, where and when we learn, with radical shifts in the way we search, communicate, collaborate, create, share, play and learn. Technology is now a pedagogic engine, changing and shaping the very way we learn, and it is accelerating, resulting in more pedagogic change in the last 25 years than in the last 2,500 years. This book is the story of that acceleration and its impact on our species.

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