Technology, innovation and management

About this free course

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Introduction

We live in a world where the history of technological innovation and change (and its organisational equivalent) has been nothing short of remarkable. Indeed, it has long been recognised that these two forms of innovation sit at the core of capitalism and largely account for the 'success' of capitalist societies over other forms of economic and social relations (Harvey, 2010). Approaching this issue from entirely different ideological perspectives, Karl Marx in the nineteenth century and Joseph Schumpeter in the mid twentieth century both recognised technological and organisational innovation as a fundamental feature of the 'creative-destructive' tendencies of capitalism, although the extent to which the costs of the destructive aspect of this phenomenon are considered acceptable is a subject that divides opinion to this day.

This free course, *Technology, innovation and managment*, introduces you to a range of related concepts, ideas and debates that will enable you to develop a critical understanding of technological innovation and management.

This OpenLearn course is an adapted extract from the Open University course T848 *Managing technological innovation*.

Learning Outcomes

After studying this course, you should be able to:

- understand the issues around defining ‘technology’, ‘innovation’ and ‘innovation management’
- recognise the diversity of types of innovation, innovators and innovation settings
- understand the nature and extent of technological change and innovation
- critically assess and explain key current issues in our understanding of innovation as a field of study.

1 Introducing technology, innovation and management

Many of us would probably accept that technological and organisational innovation is often something of a double-edged sword: as new developments occur they inevitably destabilise existing technological and organisational arrangements, and sometimes social and economic relations more broadly. One common result, for example – and one with which many of us are familiar – is what often seem to be endless cycles of organisational change, and the constant pursuit of technological ‘fixes’ that, if the claims made for them are to be believed, result in cheaper, more efficient and productive work processes.

Similarly, developments in information and communication technology (ICT) have transformed many aspects of the teaching and learning environment. Less than a decade ago you would have had to visit one of our offices to look through printed teaching materials that were the main medium we used. Since then we have moved to having materials online, and through the Open University’s OpenLearn website, which allows free access to teaching material, you do not need to leave your home. This is, however, only a relatively limited example of this innovative approach to education which may, in time, signal ‘the end for the traditional university’. To learn more about the potential for developments of this kind read the news article from *The Guardian*.

2 What is innovation?

As we noted in the introduction, Joseph Schumpeter, a seminal thinker on innovation and economics, argued that capitalism is fundamentally a system of change; capitalism is incapable of remaining static (Schumpeter, 1934). He describes the 'perennial gales' of 'creative destruction' unleashed by innovation. In 1912 Schumpeter made an early characterisation of innovation as any of five phenomena:

- the introduction of a new good
- the introduction of a new method of production
- the opening of a new market
- access to ('conquest of') new sources of raw materials or components
- the introduction of new forms of organisation.

(Godin, 2008)

The term 'innovation' has since been extensively debated, and used in a wide range of ways. One study (Baregheh et al., 2009) identified 60 definitions of innovation in organisations alone. In part, at least, these differences are a result of the different concerns of different academic disciplines, the perspectives of different stakeholders in the innovation process and the different contexts in which innovation is considered. Whereas an economist may be concerned with the contribution of innovation to the performance of a national economy and so be interested in the generation of entirely new products or processes, a social scientist interested in how individuals decide whether or not to adopt an innovation may be concerned simply with whether a product is new to an individual. Managers may be concerned with how to prepare their organisation to generate innovations that are new to their industries and markets or with how their organisation might most effectively adopt or configure innovations generated elsewhere for use in their own structures and practices. What the term 'innovation' means, then, appears to depend on who is using the term and the context in which it is used. In the next section we look in a little more detail at some of these uses.

2.1 Definitions and types of innovation

Firstly, the broad definition of innovation that we have used as our starting point in this course is the widely used definition of innovation set out in the *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data* (OECD, 2005). This definition comes from a wider tradition of research into the measurement of innovation. It is used by organisations such as the Organisation for Economic Co-operation and Development (OECD) and the Commission of the European Communities (CEC) to inform innovation policy. This sets out four main types of innovation (OECD, 2005):

- Product innovation – a good or service that is new or significantly improved. This is perhaps what we think of most often when we think of an innovation. Recent examples of product innovation would be 'smart' phones and tablet computers.
- Process innovation – a new or significantly improved production or delivery method. Innovations in the way things are made can critically effect, for example, how widely accessible they are. A recent, and widespread, example would be the shift in many

retail sectors such as clothing, books and groceries to online sales and associated distribution.

- Marketing innovation – a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. The English football Premiership might be seen as an example of marketing innovation. The old First Division was replaced by a new organisation that sold broadcast rights via a new television provider, making the English Premiership perhaps the richest football league in the world. Essentially the same product was repackaged and made available via paid-for subscription satellite TV.
- Organisational innovation – a new organisational method in business practices, workplace organisation or external relations. Open source software is organised very differently from conventional software development and has become an important source of software such as the Linux and Android operating systems and a wide range of applications (including the Firefox browser and Zotero reference management system).

The OECD definition focuses on what is innovated – product, process, marketing or organisation – rather than how or why people or organisations choose to use an innovation, or how an innovation might be produced. In 2005, the inclusion of marketing and organisational innovation in the definition used in the 3rd edition of the *Oslo Manual* represented a broadening understanding of innovation and the recognition of the increasing significance of non-technical innovations. It is a particularly significant definition in that it is used to inform policy making at European and international levels.

2.1.1 Innovation as process

In the UK, the Department for Business, Innovation and Skills (BIS) defines innovation as follows:

> Innovation is the process by which new ideas are successfully exploited to create economic, social and environmental value.

(BIS, 2012)

This definition draws our attention towards how innovation happens – 'the process by which new ideas are successfully exploited'. This is central to the management of technological innovation, and hence to much of this course. The new idea or invention is not by itself enough; it needs to be part of a wider process that realises value. Figure 1 illustrates this process of innovation as a series of activities progressing from 'idea generation' (loosely, invention) through to marketing and adoption in the market place ('diffusion'). This happens in the context of the 'push' of new technologies ('state of the art in technology and production') and the 'pull' of societal and economic demand ('needs of society and the market place'), which are discussed in Section 5.

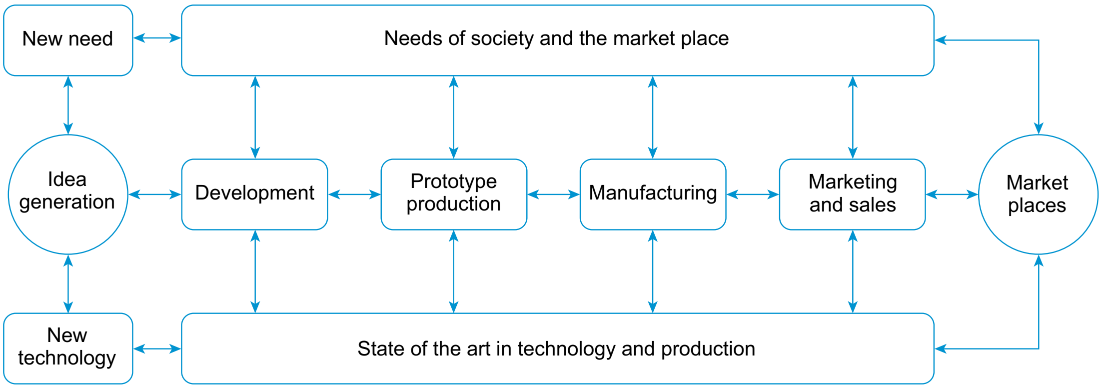

Figure 1 The coupling model of innovation (adapted from Rothwell, 1992)

This is a rather stylised and simplified model of innovation. For example, it portrays innovation solely in relation to manufacturing, whereas service innovation currently represents a hugely significant arena. It does, however, encourage us to think of innovation as a complex process. You will also see, later in this course, that it draws on a model of innovation that has undergone significant revision and refinement. For now, though, it serves our purpose of recognising that innovation is a process that happens in both technological and socioeconomic contexts which it both influences and is influenced by.

2.1.2 Adding value

A second element of the BIS definition is the idea of value. As we have already noted, this value may be realised in economic terms but potentially also in social or environmental terms. These areas are both increasingly seen as critical elements and domains of innovation.

2.1.3 Diffusion

The final definition of innovation that we consider is from the work of one of the most influential writers on the diffusion of innovations, Everett Rogers, and is concerned primarily with how innovations spread. Rogers has defined innovation as follows:

> An *innovation* is an idea, practice or object that is perceived as new by an individual or other object of adoption. It matters little, so far as human behaviour is concerned, whether or not an idea is 'objectively' new as measured by the lapse of time since its first use or discovery.
>
> (Rogers, 2003, p. 12)

As Rogers is concerned primarily with why people and organisations decide whether or not to adopt an innovation, it matters less whether that innovation is absolutely novel than that it is new to a would-be adopter and the circles in which they move. An understanding of how and why a target audience of people or organisations decides about an innovation can be critical to its success or failure. We will look at elements of the diffusion of innovation in a little more detail later in this course.

Activity 1

Now you have been introduced to a range of ideas about – and definitions of – innovation, watch these five short clips from the Open University/BBC co-production *Built in Britain* (2012) in which a range of interviewees talk about examples of innovation and related issues.

Videos 1–5: Watch all five videos

Video content is not available in this format.

Video 1: Interview with Andrew Wolstenholme of Crossrail

Video content is not available in this format.

Interview with Rob Holden of HS1

Video content is not available in this format.

Interview with Colin Matthews of BAA

Video content is not available in this format.

Interview with Ken Burgin, Chief Executive of the Cotswold Canal Trust

Video content is not available in this format.

Interview with Evan Davis of the BBC

3 Who are the innovators?

Probably because of the way in which the history of innovation is reported in the media, newspapers, books and elsewhere, misconceptions have emerged about innovation and the innovation process. One of the most common image/stereotype is of the lone 'boffin' inventor working tirelessly day and night in his workshop (or garage or shed) to realise a long dreamt of idea that will result in an invention of ground-breaking significance. This may be an idealised exaggeration, of course, but something similar has become a powerful image that is often associated with innovation. How often have we heard the stories of Bill Gates (www.microsoft.com), James Dyson (www.dyson.co.uk) or Steve Jobs (www.apple.com)?

3.1 Individuals and groups

Leaving aside for now the fact that the common stereotype conflates innovation and invention, it is, however, not typical of reality. Individuals can and do play a pivotal role in how innovations arise and develop, of course. But in many cases innovations happen through dogged hard work, chance or even imitation. Much of this activity will have taken place within and between groups or teams of people, rather than residing in the ideas and work of an individual. We must, of course, also recognise that some examples of innovation (and invention) – perhaps more than we imagine – have their origins in espionage and theft.

So, individually or collectively generated ideas play a crucial role in innovation – as they do in invention. But in many ways generating and capturing ideas is the relatively easy part of the process. As Pfeiffer and Goffin (2000) noted, the more difficult part is putting good ideas into practice and, perhaps even more importantly, gaining value from so doing. This always involves adapting and modifying the original 'raw' idea to serve an organisation's internal and external circumstances. This is why in many organisational settings where innovation is regarded as a key element of strategy the 'ideal' employee is someone who can work in a research capacity, then move through to developing (for example) a new process, a saleable product or a valuable service.

3.2 Beyond product innovation

There is also a tendency to think of innovation only in terms of new *products*, particularly as we are regularly bombarded with advertising for such 'stuff', as we note later. Yet arguably the greatest single innovation of the 20th century, the one which most changed society, the patterns of living and our economies, was not a new product but a *process, a way of producing a product*. Henry Ford's production line for manufacturing cars made them affordable for the first time to people on moderate incomes. It also had a profound impact on the way in which work within Ford's factories was structured and carried out. Ford introduced the production line, with workers carrying out the same tasks, at a set speed, over and over for the duration of their shift.

The benefits (and costs) arising from Ford's innovation obviously had a profound impact on the world for consumers, manufacturers and more widely. There are, of course, many newer examples of technological innovations (and inventions) that have enabled more wide-ranging process and organisational innovation. Advances in ICT enabled the process and organisational innovations that led to the advent of call centres, often in locations that bore little or no relation to the location of the customers who had to make use of them. As in Ford's production line and its contemporary examples, the technology used in call centres has not only impacted organisations and their customers, but also on the way work is structured and controlled. It is worth noting, however, that evidence has existed for some years that shows organisations that are first to market with an innovative product or services are frequently less successful than those which follow on later (Rogers, 2003; von Hippel, 2005).

3.3 Beware of the hype

Clearly some examples of innovation signal important actual or potentially wide-ranging intended (and unintended) impacts and consequences. We need to treat some of the claims for the transformative power of certain examples of innovation with care. Online shopping may be relatively 'new' and convenient, and Facebook may have ushered in an age when people could have an almost infinite number of 'friends' regardless of their location or whether they have actually met. However, shopping without physically entering a shop (so called mail order or catalogue shopping), and 'virtual' friendships (pen pals writing letters to each other, often without having met) both existed long before the advent of the internet. Both were made possible by innovations that were ground breaking in their day. Compare also the impact of the introduction of running water, electric lighting and indoor plumbing with some more recent 'innovations'. As Chakrabortty (2012) comments, 'You might love your iPhone, and I might spend too much time on Twitter, but we'd both be fine if they'd never been invented.'

Wilby (2012) continues in a similar vein when he notes that:

> Supermarkets are full of things that claim to be 'new and improved'. Technologists tweak vegetables and fruits to make them last longer and look better, without regard to flavour. Bankers develop 'products' that, however you cut it, are still about borrowing and lending. We have digital radio and high-definition TV, though not everybody thinks either improves on what existed before.
>
> (Wilby, 2012, p. 33)

We can debate the extent to which a new product or service is innovatory, or not, of course, with our conclusion perhaps being more dependent on perception than fact. There is one feature of our modern day consumer culture that, although a recognised feature of the innovation process since the 1950s, has, as Wilby goes on to note, become all too dominant:

> For many companies, skilful marketing has replaced innovation. It's cheaper and less risky to convince customers something is groundbreaking, even if it isn't, than develop something truly innovatory.
>
> (Wilby, 2012, p. 33)

Interestingly the use of the term 'innovation', and our willingness to attribute ground-breaking powers to it, also seems to parallel the way in which 'entrepreneur' and 'entrepreneurialism' have become idealised – almost mythical – constructs over the latter part of the 20th and into the 21st century. In both cases it often seems that we are asked to believe that if countries can be more innovative and entrepreneurial, then economies will automatically grow and societies benefit. However, we should take a moment to think more critically about some of the claims for entrepreneurialism and innovation. We might, for example, question the extent to which a commercial organisation (or its CEO/owner) taking over a service that was previously run by the state – such as a railway, prison, water company or services for unemployed people – is really being entrepreneurial or innovative in so doing.

In reality the overuse of both terms is in danger of devaluing their utility. It is for this reason that we want you to maintain a critical awareness of innovation and claims for its potential and power as you work your way through this course. We expand on the subject of assessing and evaluating technological innovation later in this course, but before we do, it is appropriate at this point to take a brief detour to introduce and discuss two related aspects of innovation that stem from the ways in which we understand and interact with technology.

Activity 2

Before reading further watch this short interview with Sir George Buckley, former CEO of 3M, which covers a range of topics we have introduced so far.

4 The meaning of ‘technology’

Although this course focuses on the management of *technological* innovation, you will notice that in our discussion so far this has often simply been abbreviated to *innovation*. On one level the reason for doing this is simple – to avoid constant repetition of the longer term. There are, however, two other important reasons. The first stems from the fact that almost all innovations have a technological dimension or component. Consequently, almost all examples of innovation and technological innovation can be regarded as one and the same thing. This has always been true of product innovation, but became an increasingly important feature of organisational innovation from the industrial revolution onwards and especially since the advent and subsequent convergence of ICTs.

4.1 Defining technology

The second stems from how we define *technology* for the purpose of this course. Put briefly, we see technologies not simply as technological *artefacts*, such as an iPhone or laptop, but also as *knowledge*. If you have not thought of technology in this way before, it may seem odd but you will actually find very few definitions of technology that only refer to technology as artefacts. An accurate definition will also include reference to a body of knowledge and practice (often referring to the application of scientific knowledge, although the emphasis on scientific is, in fact, too narrow). Indeed, we could say that technology as artefact and knowledge represent two of the components of the ‘bundles’ of *assets*, such as specific forms of intellectual property, organisational capabilities, complementary technologies and even commercial brands that together provide potentially innovative products and services.

A further distinction can be made between technology as *mode of enquiryand action*. This refers to the techniques by which technological knowledge is itself created. For example, a particular approach to *continuous improvement* that used to get a lot of attention in innovation management literature in the early 1990s and has endured into the 2000s is the Japanese ‘Kaizen’ model, which, it was argued, was particularly effective for organisations that needed to deal with high rates of change and complexity in their operations and environment.

Interestingly, mention of process improvement brings up another very important distinction in the meaning of technology, which is between *process* and *product* technologies. The former is what an organisation uses to accomplish its tasks. The latter is delivered to customers. *Product in this context means both goods and services*.

4.2 Hierarchies of technologies

Technologies are also connected in extensive *hierarchies*. By this we mean that component technologies and tool technologies are products that are applied within other product and production technologies, respectively. For example, although there may be few obvious components when you look at a car from the outside, many would have been added as it made its way along an assembly line, not least an internal combustion engine; whereas the welding machine that assembled the body panels represents tools. From the viewpoint of engines and welding machines, cars, assembly lines and other containers represent application technologies. Even the car may have been applied within another technology, probably a service operation such as a taxi service or police car.

The hierarchy connects not only technologies but also the organisations that produce and apply them. In the case of the car, a plant produces engines, whereas external suppliers produced many other components and tools such as the welding machines.

If we were to ask you to describe a particular technological artefact according to the distinctions in Section 4.1, you would also have to describe the *perspective* from which you were answering. This is because one person's component (or tool) is another person's product and yet another person's application. This illustrates both the limitation and the usefulness of these categories. They are limited because they convey only relative meanings. They are useful because they help us to characterise and divide up technological innovations from the perspective of a particular organisation. Therefore, in larger organisations there will probably be a mix of approaches to acquiring and using technology. For example, one firm might innovate production technology but buy in tools.

Categorisation

Here is some guidance on categorisation to help you with Activity 3:

- Product mode of enquiry and action might be a particular approach to research and development.
- Product knowledge is about architecture and design (NB not designing), e.g. the arrangement of components in a successful working whole and the trade-offs that achieve the desired performance.
- Product artefacts are component technologies within the product. (Note: the knowledge and artefacts incorporated in a product may be indiscernible to its users.)
- Process knowledge is about the systems of operation and control, craft practices, and so on that produce the product.
- Process artefacts are the tools used in these systems and practices.
- Process mode of enquiry might be a particular approach to process improvement.

We suggest a template in Table 1 for analysing the meanings that an organisation bestows on its technology. Of course, because one technology's product may be another's component, a hierarchy of tables might be useful in some cases. We have put ideas into Table 1 representing our view of a hydraulic crane and an imaginary pharmaceuticals firm which is developing a 'natural' medicine. The reason we want you to undertake a similar exercise is so that you can relate the distinctions to your own experience and/or organisation.

Table 1 Meanings of technology

	Artefact	Knowledge	Mode of enquiry and action
Product	Hydraulic rams	Heavy mobile equipment architecture and design	Market-driven invention/ innovation
	Bio-active ingredients	Structure of molecules	Systematic search for and analysis of medicinal plants
Process	Robots, lathes, control software	Heavy vehicle production	Continuous process improvement

Fermenters	Drug testing and approval system	Continuous process improvement

Activity 3

To illustrate the distinctions made in Table 1, we want you to think of two examples based on your own experience or background.

4.3 Viewpoints and meanings

Finally, it is also important to remember that technologies mean different things to different people at different times and places (in other words, it is contextually and temporally sensitive). An interesting historical example relates to one of the most successful early cars – the Ford Model T. Rural customers used it for towing a plough. Lacking electricity the same customers also used it as a source of power to drive farm machinery and generate electricity (by propping the vehicle up on blocks and running a belt from its drive wheels to the equipment or dynamo). Note: this is another example of the car as an application technology.

It is not only customers who interpret technology in various ways, of course. One well-known and relatively recent example was the music industry’s initial response to digital music downloading: litigate against any download service it could identify (such as Napster). The industry saw this new technology as a disruptive threat that needed to be destroyed if it could not be controlled. However, once the rule of copyright had been re-established in the digital domain, it did not take long for the industry to realise that this new technology actually supported an entirely new business model. A small irony is that this is now the business model that dominates music sales – as any user of an iPhone or subscriber to Spotify will know only too well – and the sale of all kinds of other ‘applications’.

All of the distinctions noted in this section are important because they clearly illustrate why the management of technological innovation is far broader in its scope and interest than simply focusing on technological artefacts. We discuss this subject in more detail in the next section.

5 The nature of technological change and innovation

In this section you will look at advancements in technology down the years.

5.1 Waves of change?

If you take the time to read the fairly wide range of literature devoted to examining and analysing technology and technological change – or specific examples of it – it is unlikely that you will not, at some point, come across a discussion of 'technological paradigms' or, alternatively, 'technological revolutions'. We have previously mentioned in Section 2 the work of Schumpeter (1934), who made the observation that technological innovations appear to emerge in clusters over time. If you are familiar with economics you may also have come across the term 'Kondratieff cycles' (named after a Russian economist) or 'long waves'. Kondratieff posited that each cycle lasted on average 50 years and was

> based upon technological innovations that bundle together in a particular place and time to set the stage for steady development and diffusion outwards until a new bundle of innovations comes along and supersedes the first.
>
> (Harvey, 2010, p. 96)

Each paradigmatic period, or wave, is marked out by the features described in Table 2. Note that the beginning and end dates for the periods *do not* signal that at that point the particular key carriers and key industries disappear or even cease being important. Clearly railways and canals developed in the 18th and 19th centuries still exist, and are to a greater or lesser degree still important economic (and social) assets in many countries. Similarly, Fordist mass production still maintains its importance, although the technologies that underpin it have, in many industries, changed radically. The important point is that during each period there are key industries and 'carrier' sectors which are then superseded as the key industries/carriers over time. The timing and speed of this change may vary, of course, from location to location.

Furthermore, despite the impression that the elements of Table 2 might give, these developments are not solely determined by technology and technological development, as Castells (1996) notes 'many factors, including individual inventiveness and entrepreneurialism, intervene in the process of scientific discovery, technological innovation, and social applications, so that the final outcome depends on a complex pattern of interaction.' He continues:

> Thus, when in the 1970s a new technological paradigm, organised around information technology, came to be constituted, mainly in the United States, it was specific segments of American society, in interaction with the global economy and geopolitics, that materialised into a new way of producing, communicating, managing, and living.
>
> (Castells, 1996, p. 5)

Table 2 Waves of technological development (after Dodgson et al., 2008)

Dates	Description	Key 'carrier' sectors
1770s –1840s	Early mechanisation	Textiles Water power Canals
1840s –1890s	Steam power and railways	Steam engines Machine tools Railways Steamships
1890s–1950s/60s	Electrical and heavy engineering	Electrical and heavy engineering Synthetic dyes Electricity
1920s –1990s	Fordist mass production	Autos Airlines Consumer durables Petrochemicals Process plant Plastics Highways Armaments Aluminium
1970s –?	Information and communication technology	Computers Telecommunications Software CIM New materials ISDN IT services
2000s –?	Life sciences	Biotechnology Space/satellites Environmental technologies ?

As you will note from Table 2 and the quotation from Castells (1996), the ICT paradigm was, therefore, the fifth wave – or techno-economic paradigm. There is, however, an increasing belief that we have already – or are on the cusp of entering – a sixth wave based around the life sciences (Dodgson et al., 2008). To what extent, where and how rapidly the key industries and carriers of the sixth wave supplant those of the fifth is something we can observe as we move further into the 21st century.

5.2 'Generations' of innovation

Such is the perceived transformational power of technology that there has long been a tendency to uncritically accept such claims. One of the most significant outcomes is the widespread belief that there must be a technological 'fix' for almost any problem. Examples of this (sometimes with the caveat 'if only we throw enough money at it', or something similar) are many and varied, as Activity 4 should demonstrate. Consequently, we will only highlight one example, here, but one where the nature of the problem it may fix has changed over time.

GM (genetically modified) crops/foodstuffs have long been regarded as a technological fix to the real or potential problem of food shortages caused by population growth (by increasing crop yields and/or for use on land not previously considered fertile enough to grow crops). However, as climate change has become a more accepted and widely recognised issue so the potential use of GM crops as a technological fix for this problem has also developed. Consequently, it is argued that we can probably lessen or compensate for the impact of climate change through the development and use of GM crops that are able to withstand more extreme variations in temperature.

Activity 4

Drawing on your current or past professional experience, note down an example that you are familiar with of a technological fix to a problem/issue. Also note down the nature of the problem. Now think of a solution for this problem or issue that would not involve technology.

The same deterministic logic that underpins the claim that there is a technological fix to almost every problem is also evident in two of the most frequently cited and commonly discussed models of what 'drives' innovation: *technology push* and *market pull*. Also known as research-push and demand-pull, or first- and second-generation innovation (Rothwell, 1994), respectively, a simplistic interpretation of these terms is that technology push is represented by a technology searching for an application, and market pull as an industry response to observed market demand. As we shall see, several more explanations of the innovation process have been developed since the push and pull models appeared, but there are good reasons why these concepts emerged when they did and what they tell us about innovation at that time.

5.3 Technology (research) push

The push model assumes that the source of technological innovation is through formal research and development (R&D) and that when the outcome (whatever it may be) has been developed and then produced/manufactured, it is then 'pushed' by marketing and sales out into 'the market'. This is basically a very simple linear innovation process (Figure 2).

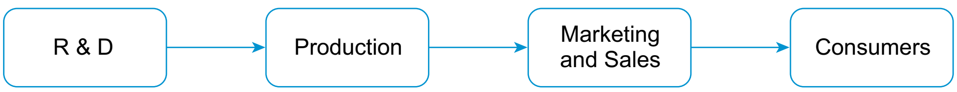

Figure 2 The first-generation innovation process

In many ways it is unsurprising that the ‘push’ model of innovation became popular at a certain point in time because it accurately reflects a process that became commonplace in the two decades after the Second World War (Dodgson et al., 2008). This was a period when a strongly deterministic belief in technology (and science) was at its peak, with the dominant view being that technological development was inevitable and almost always positive, and that scientific and technological advances could solve most of the world’s problems. This led governments actively to promote and support scientific and technological innovation, through direct support for R&D programmes (often in government-owned centres) and through support to universities. This is the basis for many of the government-run, -sponsored or -supported *systems of innovation* that still operate in many countries.

Commercial organisations – particularly in manufacturing – also played a key role in R&D as they sought to respond to the post-war boom in demand for consumer goods, such as fridges, washing machines, electronics and cars. Government and industry came together to respond to the ‘Cold War’ by pouring money into R&D in the defence industries (e.g. aircraft, ships, vehicles, armaments, munitions and electronics) and, later, space programmes. As Rothwell (1994) notes, the focus on scientific discovery and R&D as the primary drivers of innovation over this period led to the ‘first generation, or technology push, concept of innovation [that] assumed that “more R&D in” resulted in “more successful new products out”’ (Rothwell, 1994, p. 8).

It is during this period that we begin to see the development of products with the potential for domestic application being ‘spun out’ of industrial innovations and inventions. One well-known example is Teflon, a trademarked brand name of PTFE, a highly ‘non-stick’ substance discovered by accident in 1938. Its use in industrial and military settings was extended to domestic applications in 1954 when it was used to provide a non-stick coating for cooking pans and utensils – the Tefal brand we still see today.

5.4 Market (demand) pull

Market or demand pull is, as the term suggests, something of an opposite to the ‘push’ model. ‘The market’ – consumer/customer demand – ‘was the source of ideas for directing R&D which had a merely reactive role in the [innovation] process.’ (Rothwell, 1994, p. 8). The pull process is therefore slightly more complex than the push example, and is still based on the same linear model (Figure 3), but with the addition of market/demand inputs at the R&D and marketing stages.

This ‘second-generation’ model of the innovation process again very much reflects the context in which technological innovation was taking place from the mid 1960s to early 1970s, and thus the economic and social developments of the time. Demand for new products and services remained strong but with intensifying competition between producers, and a change of emphasis in investment in technology. As Rothwell (1994, p. 8) notes, ‘This was accompanied by growing strategic emphasis on marketing, as large and highly efficient companies fought for market share. Perceptions of the innovation process began to change with a marked shift towards emphasising demand side factors, i.e. the market place.’

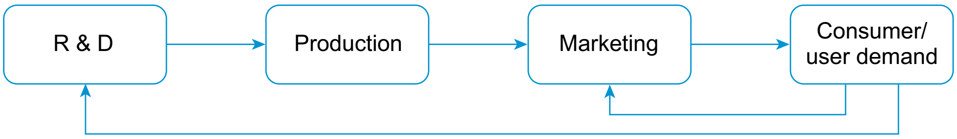

Figure 3 The second-generation innovation process

5.5 Third-generation innovation

The technology push and market pull models of technological change and innovation offer simple – and therefore attractive – explanations of the innovation process with only a partial explanation of the mechanisms or drivers that are significant for innovation. Indeed, following the publication of a wide range of empirical studies of innovation in the mid to late 1970s, it was argued by Mowery and Rosenberg in 1978 that:

> Essentially, these empirical results indicated that the technology push and need [demand] pull models of innovation were extreme and atypical examples of a more general process of interaction between, on the one hand, technological capabilities and on the other, market needs.
>
> (Mowery and Rosenberg (1978), cited in Rothwell, 1994, p. 9)

As a result a 'third-generation' model of innovation was proposed. In Figure 4 this model 'couples' together a range of functions, activities and 'communication paths':

> The emphasis in this model is on the feedback effects between downstream and upstream phases of the earlier linear models. The stages in the process are seen as separate but interactive. The management challenge of this process involves significant investment in cross-organisational communications and integration.
>
> (Dodgson et al., 2008, p.62)

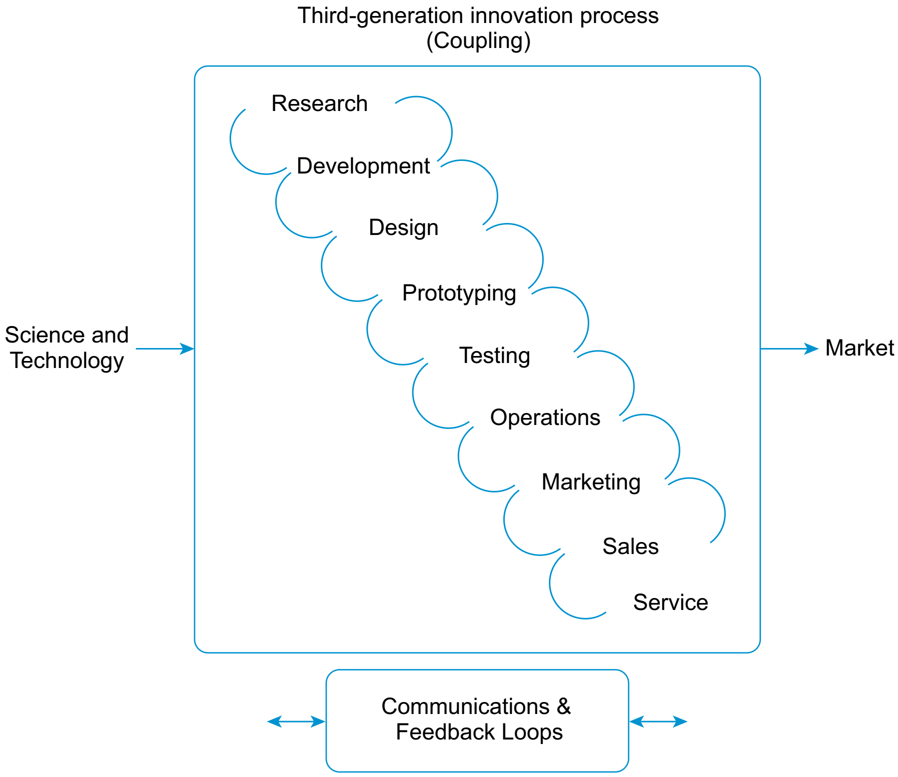

Figure 4 Third-generation innovation process (Source: Dodgson et al., 2008)

5.6 Fourth-generation innovation

The third-generation model of the innovation process may have contained challenges but as Rothwell (1994, p. 10) notes, it 'was seen by most western companies, certainly up until the mid 1980s or so, as presenting best practice.' Nevertheless, by the mid 1980s a further refinement of the model was necessary as Western organisations increasingly realised that the key features of the innovation process in leading Japanese companies – and thus one of the primary reasons for the commercial success of Japanese companies – were integration and parallel development. That involved integrating 'suppliers into the new product development process at an early stage while at the same time integrating the activities of the different in-house departments involved, who work on the project simultaneously (in parallel) rather than sequentially (in series).' (Rothwell, 1994, p. 12). Therefore, integration and parallel development become the basis of the fourth-generation model of the innovation process (Figure 5).

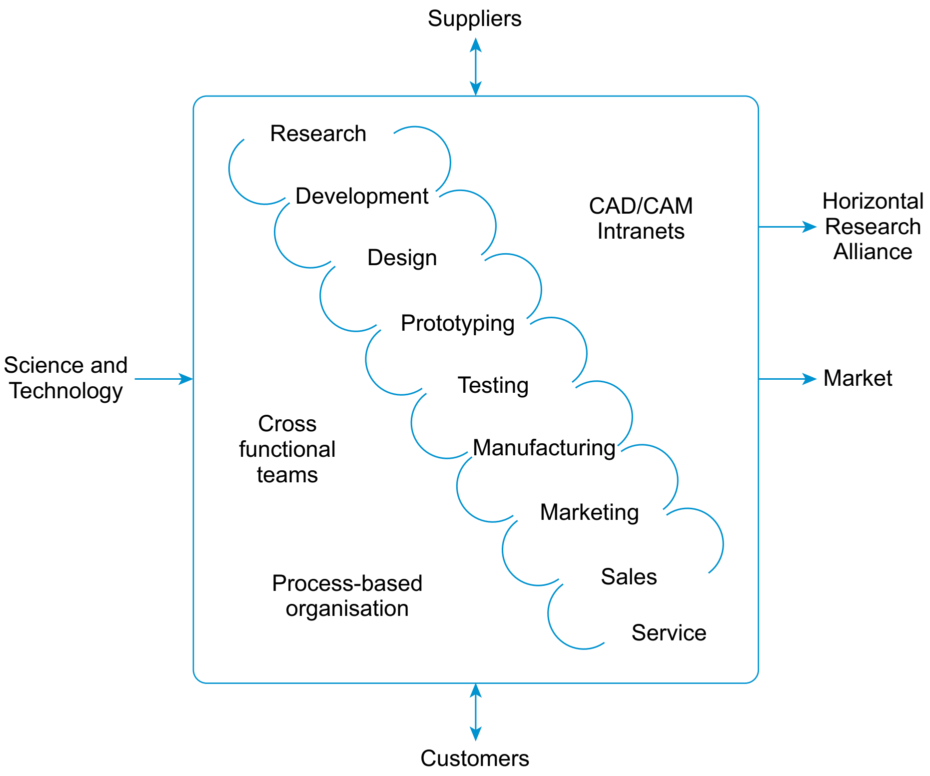

Figure 5 Fourth-generation innovation process (Source: Dodgson et al., 2008)

5.7 Fifth-generation innovation

It is argued that by the early 1990s a new model of the innovation process began to emerge (Rothwell, 1994; Dodgson et al., 2008), which, following Rothwell's labelling convention, became the fifth-generation innovation process. Figure 6 illustrates the key aspects of this model, which requires managers to respond flexibly to deal with increasing level of risk and uncertainty:

> Within the firm we see increasing concern with organisational forms and practices and skill balances that enable the maximum flexibility and responsiveness to deal with unpredictable and turbulent markets. Research, development, design and engineering take place in concurrent iterations, supported by 'innovation technology' in a fluid model [that Dodgson et al. refer to as 'Think, Play, Do'] … The value-creating activities of the firm are linked with suppliers and customers, and all the technological activities in the firm are directed by increasingly coherent and effective innovation strategies.
>
> (Dodgson et al., 2008, p. 64)

Some of the key features of the fifth-generation process – such as technology transfer and open innovation – will be discussed in more detail later in the course.

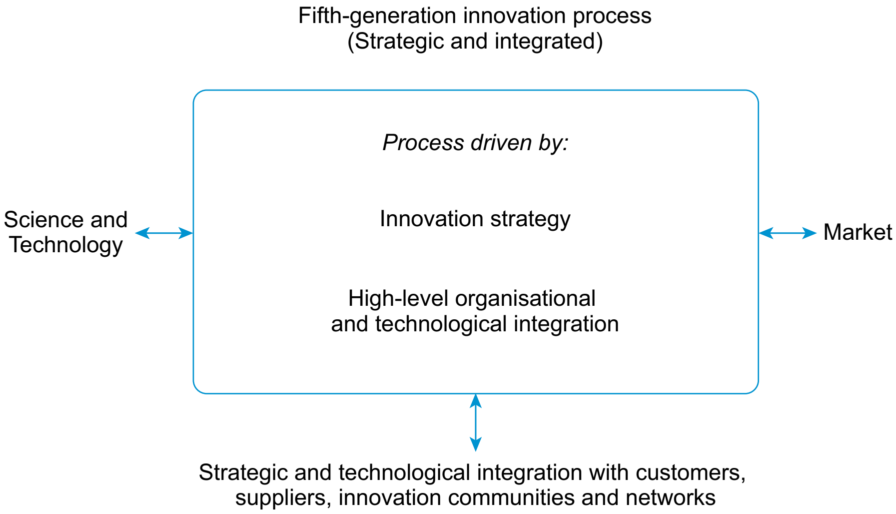

Figure 6 Fifth-generation innovation process (Source: Dodgson et al., 2008)

In suggesting (and discussing earlier in Section 5.1) that we are currently experiencing a transition from the fifth (IT) to the sixth (life sciences) wave of technological development, there has been a similar debate as to whether a further sixth-generation model of the innovation process has emerged. Unfortunately there is not the space here to enter into that debate. There is, however, one more variant of the innovation process that should be highlighted before concluding this section of the course and looking at innovation management specifically.

5.8 Market driving innovation

The acclaimed HBO TV series *Mad Men* follows the emergence and development of the advertising industry in the USA through the 1950s and 1960s. If you have watched the series you will be familiar with the extent to which consumer demand or need became an increasingly important feature of the market for consumer goods of almost every type during this period. The reasons for this – and the challenge created for manufacturers and retailers – are worth noting:

> The rise of social science subjects, such as human and economic geography and the sociology of consumption, generated new ideas about markets and demand, informing and advising governments, which developed 'predict and provide' policies. It was also a time of growing consumer awareness and movement, such as those demanding greater automobile safety. The management challenge of this process is relatively simple: invest in marketing.
>
> (Dodgson et al., 2008, p. 61)

Identifying consumer demand was a key feature of the second-generation model of innovation, and marketing became a recognised feature of the third generation. There is, however, another dimension to marketing/advertising activity that becomes increasingly evident as the *Mad Men* series develops (i.e. as they move deeper into the 1960s). This is the extent to which manufacturers and retailers try to *create* (and then maintain) demand for a product or service, usually through clever, highly visible advertising and other forms of marketing. In some cases this has been a highly successful strategy. Indeed, by the early 2000s a study that included in its research sample several commercial organisations that were, at that time, recognised as extremely successful concluded that:

> Firms are constantly exhorted to become more market driven. However, our study of 25 pioneering companies (e.g. Body Shop, IKEA, Tetra Pak) whose success has been based on radical business innovation indicates that such companies are better described as market driving. While market driven processes are excellent in generating incremental innovation, they rarely produce the type of radical innovation which underlies market driving companies. Market driving companies, who are generally new entrants into an industry, gain a more sustainable competitive advantage by delivering a leap in customer value through a unique business system. Market driving strategies entail high risk, but also offer a firm the potential to revolutionize an industry and reap vast rewards.
>
> (Kumar et al., 2000)

Legislation, regulation, funding, location and even fashions or fads can also be causally significant in driving innovation. However, we now want to turn our attention to a more in-depth examination of the relationship between management and innovation.

6 Innovation management

Here, we explore and define the many aspects of technological innovation.

6.1 Early development

If you think back to the discussion of the first-generation innovation process that was a feature of the immediate post Second World War period, it should be fairly obvious that innovation management (IM) was at that time largely seen as involving a relatively limited *range* of people with what we can broadly define as creative and/or technical skills relating to R&D (e.g. scientists of various types, draughtsmen and engineers), product development, manufacturing and sales and marketing. By the 'second-generation' – from the mid 1960s – this pool of people and expertise continued to evolve, encompassing as it now did the requirement to identify markets (consumer demand or need) and use more dynamic and wide-ranging approaches to marketing and sales.

Identifying consumer need/demand also led to an increasing awareness – in the USA initially and then more widely across the industrialised world – that the market for consumer goods was far wider than had been imagined through the 1950s, with a resulting growth in R&D into products (and services) previously not considered as having a consumer, and thus commercial, application. Overall then, and as we have previously noted, although the linear models of first- and second-generation innovation are oversimplified and thus do not, for example, reflect variations between industries, sectors and even organisations, they do suggest an approach to innovation management (and management more generally) that is logically sequential and likely to be relatively fixed and static over time.

6.2 Evolution and change

If you return to Figures 4, 5 and 6 and look first at the diagram of third-generation innovation (Figure 4) and then at the subsequent diagrams (Figures 5 and 6), it is obvious that as the innovation process in most settings (e.g. commercial, public, products, services, etc.) evolves, it becomes more differentiated and diversified. It follows, therefore, that innovation management must similarly evolve – as the brief summaries of the three models actually indicate. Let us take a brief example to illustrate this further. For several decades designs for anything from toilets to TVs were drawn out manually by draughtsmen, many hundreds of whom would be employed to work on complex projects such as a new car. The drawings (plans, diagrams, etc.) they produced were then used by a range of skilled workers, such as pattern cutters, tool makers, panel beaters and so on, to manufacture the technologies and components that were used to produce the final product.

By the late 20th century – the ICT wave of technological development – many of the specialist activities that form part of innovation processes – particularly in design, development and manufacture – were being carried out using ICTs and pre-programmed technologies (i.e. computer-aided manufacture – CAM). The result was a reduction in the number of people involved in some activities and a change in the mix and skills sets of the specialisms that remained (e.g. from being skilled in the use of drawing board, pencil, set square and slide rule to being able to use the latest CAD applications). By contrast, other parts of the innovation process grew in scale, scope and importance. As we noted previously, marketing would be one example, as would legal and administrative services related to intellectual property (IP).

The fourth-generation innovation process signalled the need for increasing investment in – and thus the challenge of managing – cross-organisational communications and integration, whereas the fifth-generation innovation process signalled new challenges, such as dealing with high levels of risk and uncertainty. This, of course, is a very brief sketch of some of the many changes and challenges and activities, processes and practices that make up contemporary innovation management, particularly in the context of large commercial organisations and/or at the level of sectors and industries. The diversity and scale and scope of innovation management in smaller organisations and/or in public or not-for-profit organisations may well differ from the situation sketched out above, but it is clear that how organisations and individuals manage and 'do' innovation (and change) – will have – and has to have changed over time.

Now complete Activity 5.

Activity 5

Read through Section 6 again up to this point. Now using an organisation or sector that you are familiar with, think through how the innovation process and/or innovation management will have evolved over the generations of innovation. Start with the most recent first and work back as far as you can, noting down at least one example for each and briefly explaining your rationale for choosing your examples.

6.3 Defining innovation management

This raises the question, is it possible to define innovation management? There have, in fact, been several attempts at doing just that, of which we only draw on a couple of examples here. An early attempt would be Brown (1997), who concluded, on the basis of a survey of tools and techniques for managing innovation across 17 European countries, that innovation management was concerned with people, culture, communication and organisation of business processes and technology.

Interestingly – but perhaps unsurprisingly – this is similar to Bartol and Martin's (1998) definition of change management, which includes technology, human resources, organisational culture and structure. It is also worth adding that a wide-ranging review of studies of innovation management discovered that 'the terms innovation management and technology management are often used interchangeably, or rolled into one.' (Igartua et al., 2010, p. 42). Again, this is unsurprising if we remember that earlier in this course we noted that technology is almost always present in one form or another in any example of innovation/innovation process. Nevertheless, Igartua et al. go on to note that:

> On the one hand, innovation management can be defined as the creation of preconditions to promote human creativity, including strategic commitment and context management. On the other hand, innovation management can be seen as a process to foster the application of knowledge.
>
> (Dankbar (2003), cited in Igartua et al., 2010, p. 42)

Igartua et al. therefore conclude that:

> IM involves many different components and requires the management of a variety of areas, including:
>
> - the strategy of innovation
> - portfolio management
> - project management
> - leadership and organisational culture
> - human resources
> - external relations
> - organisational design
> - innovation processes
> - performance measures
> - marketing
> - resources
> - knowledge and intellectual property management
> - technology.
>
> (Igartua et al., 2010, p. 43)

> Igartua et al. finally suggest that: 'The need to manage the innovation process and context demands managers make effective and timely decisions based on multiple functions, inputs, and disciplines.' (Igartua et al., 2010, p. 44) and identify a set of 'Tools, techniques and methodologies to support the process of innovation', including:
>
> - creativity development techniques
> - technology management techniques
> - strategic management techniques
> - HR management techniques
> - business intelligence techniques
> - project management techniques
> - new product and process development techniques
> - cooperation and networking techniques
> - design management techniques
> - knowledge management techniques.
>
> (Igartua et al., 2010, p. 45)

6.4 Management or innovation management?

It could be argued that if change, innovation and technology are ubiquitous in almost every contemporary organisation, then that would mean that nearly all management is to a greater or lesser extent innovation management and that this is reflected in the scope and diversity of the lists quoted in Section 5.3. That said, we do need to sound a note of caution, which is that:

> Innovation management should not be confused with *management innovation*. The latter has been defined as 'the invention and implementation of a management practice, process, structure or technique that is new to the state of the art and is intended to further organisational goals.'
>
> (Birkinshaw et al., 2008 p.826 [original emphasis])

If we combine the discussion of how innovation management has evolved with the discussion of definitions and the lists of IM features given earlier, what becomes clear is that because 'innovation' is applied to anything from incremental change to radical innovation, the extent of the applicability or use of these roles, activities, skills and resources will be dependent on the form of innovation a person or group is involved in, and its context, and will undoubtedly change over time.

In practice, however, it is well recognised that 90 per cent of all innovation management activity is not directed at the 'revolutionary' – radical – level. For example, in the late 19th century the horseless carriage launched a revolution in automobile transportation. Since then the state-of-the-art for cars has moved on, primarily through a succession of incremental and generational-type technical changes to both the product and the manufacturing processes. These types of less than radical technological change therefore dominate most of the demands put on innovation managers, regardless of whether they are in a manufacturing or a service sector. In short, managing evolutionary or incremental change is not glamorous or dramatic, but it is where most of the work is.

6.5 Managing dynamics of change

For most organisations the days of just trying to optimise the production or delivery of a single product or service are long gone. Most organisations – whether commercial, public sector or not-for profit – are continually faced with trying to modify – and hence improve – their products or services: special versions are needed, a retailer wants an own-brand version, a national government introduces new health and safety regulations, or a market opportunity requires a simplified de-rated version. In short, the operations side of a business is forced to manage the dynamics of change on an almost continuous basis. Of course, managing change is not just restricted to managing technological change. As we made clear at the outset of this course, *technological and organisational change go hand in hand*.

Sometimes technological change leads to organisational change: the introduction of new ICTs has led many organisations to change their structure and operation/organisation. In turn, a new work organisation may demand new technical systems and technologies. An example from the service sector featuring an organisation that many people will be familiar with serves as a brief illustration. McDonald's created an innovative mass production food preparation and distribution system which it combined with flexible on-demand delivery at local franchise outlets. This network now stretches around the world. The visible, innovative food products are therefore part of a much more innovative food preparation, delivery and distribution system.

The point we are making is that there can be a wide variety of changes that underlie new products or services, along with a wider range of operations for their production, and that it all has to be managed dynamically in an integrated fashion. Much of technological innovation management is actually about managing change. At its simplest, there are a wide range of IM activities, from just making things a bit better, tidying things up, good housekeeping if you like, to the revolutionary breakthroughs that put a person on the moon. Because the possible combinations of resources, people, time, money, products, processes, services and systems can be extremely large – as the lists in Section 6.3 illustrate so clearly – there are many ways of managing technological innovation. As a result, there are lots of opportunities for getting things right and lots more for making mistakes as we try to understand what it is that we are trying to manage. Often there is no single right answer, but there are wrong ones, and lots of better ones worth striving for.

The spectrum of TMI/IM activities ranges from the operational to the strategic. Each activity complements all the others; there is frequently no sharp dividing line between where one ends and another begins, and often two will interact, rather than one taking precedence over the other. This is illustrated by the very straightforward diagram of the innovation process (Figure 7), which can also be seen as a simple representation of innovation management.

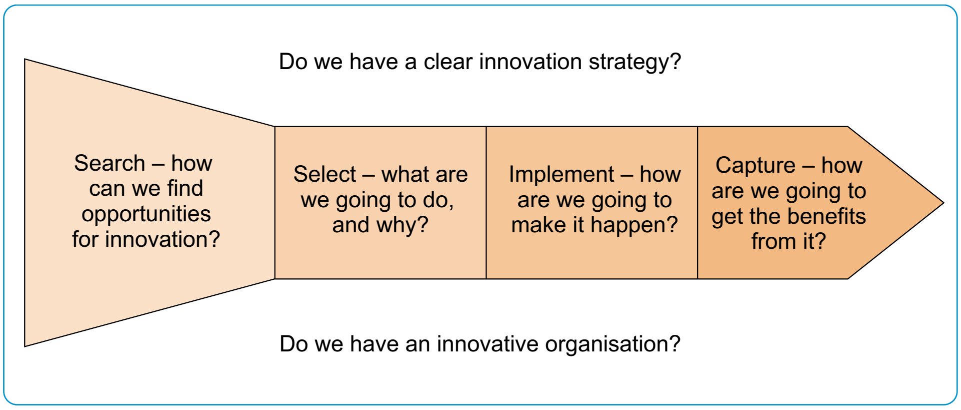

Figure 7 Simplified model of the innovation process (Tidd and Bessant, 2009)

7 Sceptical voices

In this section we discuss alternative viewpoints to contemporary concerns of innovation.

So far in this course we have looked in some detail at what we mean by terms like innovation, technology and management, and the ways in which they are often used. Before considering some of the recurring themes in current thinking about innovation, we want to take a brief detour to consider some of the arguments put forward by researchers and commentators who are more sceptical about what we might term the 'innovation agenda'.

The scale of our contemporary concerns with innovation has its critics. We noted earlier that there is frequent debate about precisely how 'innovative' particular innovations are and the extent to which the degree of innovation is a function of public relations as much as new utility. There are several strands of argument that make rather more sustained critiques of innovation (or perhaps more accurately, our apparent obsession with technology and innovation), which we look at briefly in this section.

7.1 Technological innovation and economic growth

It is frequently argued that the pace of technological change is increasing. For example, one well-known 'futurologist', Ray Kurzweil, has long argued that technology is not only developing exponentially (at least, as measured by some indicators of technological performance, most notably including the growth of computer processing speed) but that the rate of change itself is also changing exponentially (Kurzweil, 2001). So, not only is the pace of change accelerating, but the rate at which it is accelerating is also increasing. He argues that we are approaching the 'singularity' – the point at which the technology we make will itself have become more 'intelligent' than humans and hence be able to innovate (or invent) even more rapidly.

Although Kurzweil's argument might be among the more extreme claims made about the inevitability of technological change, he is certainly not alone. The UK government, for example, argues more modestly, but in a similar vein:

> A large body of evidence shows that innovative economies are more productive and faster growing. They deliver higher returns on investment and increased living standards. They are better at responding to changing circumstances through redeploying old activities and jobs. They are more able to find solutions to global challenges such as reducing dependence on fossil fuels, helping people live longer and healthier lives.
>
> (BIS, 2011, p. 5)

Others, though probably in a minority, are more sceptical and challenge such views (e.g. Cowen, 2011). US economist Robert Gordon, in a thought-provoking Working Paper for the US National Bureau of Economic Research (Gordon, 2012), has argued that the past 250 years of economic growth may prove to have been an aberration in human history. He looks specifically at the US economy (which has over recent decades been the global powerhouse of innovation and economic growth), and notes that many of the benchmark inventions and subsequent innovations of this period are 'once only'. For example, the spread of suburbs as a result of improved cars, roads and public/mass transit systems can only happen once in a place, though it may still occur elsewhere in the world. Similarly central heating and air conditioning which control interior building temperatures can only be diffused once. Roberts contradicts Kurzweil's claims about the increasing pace of technological change, using the example of the speed of mass travel. This increased from around 5 km/h (3 mph) with the horse-drawn omnibus in 1860, through the train and the car, to around 800 km/h (500 mph) with the advent of the Boeing 707 in 1958.

Speed has not only not increased since then, but actually decreased as airlines seek to reduce fuel consumption. Europeans might point to the troubled history of Anglo-French supersonic airliner Concorde, which had a maximum speed of 2140 km/h. It made its first commercial flight in 1976 before being removed from service in 2003 for a range of economic, safety and technological reasons. Arguably, Concorde never provided mass transport (only 20 were built, each capable of carrying around 100 passengers) and only serves to emphasise Gordon's argument. The main thrust of Gordon's paper is that economic growth due to innovation may consequently be lower in the future than it has been historically, and is unlikely to be enough to overcome a range of other systemic problems in the USA to maintain growth at historic trend levels, even assuming away the particular problems of the global crisis which began in 2008.

7.2 Changing rhythms of economic growth

Taking a more global view, David Edgerton, a historian of technology, argues that the rhythms of economic growth have varied globally in recent decades, including economic contraction in large parts of the world, as in the collapse of the economies of the former Soviet bloc after 1989 and the catastrophic reduction in income of the very poorest in sub-Saharan Africa during the last two decades of the past century (Edgerton, 2008, pp. 206–9).

Although there are clearly other contributory factors at play here (the political collapse of the Soviet bloc and the terrible impact of HIV/AIDS in Africa, respectively, in these examples) and there is plenty of room for debate around these issues, it seems that a simple story of technological innovation leading to increasing economic growth is not the whole story and that, at the very least, we need to be aware that this is not always so.

In a similar vein, others have argued that, in some areas, the kind of industries we have created are no longer capable of delivering meaningful innovation either at the levels they have in the past or, and even more significantly, at the levels needed to respond to important challenges facing humanity. Such arguments have been particularly strongly made about the pharmaceutical industry. Developing new drugs is very expensive and despite large investments in genomics and proteomics (the study of proteins), there appears to have been a decline in the production of genuinely novel drugs. The problem is particularly acute for antibiotics. As bacteria increasingly become resistant to 'traditional' antibiotics like penicillin ('traditional' in the sense that penicillin was discovered in the 1940s, and others shortly after, and whose use rapidly spread), there is a growing risk of untreatable, and potentially fatal, infections.

A problem less publicly articulated by the pharmaceutical companies is that antibiotics are less profitable than other forms of drugs; a good antibiotic would only need to be used for short periods, resistant bacteria are still relatively rare (and hence the market for new, expensive antibiotics is small) and are mainly in the developing world (*The Economist*, 2011). Much of pharmaceutical companies' current research aims not to address issues such as antibiotics, but to patent minor modifications to existing drugs. Bringing these to market is made easier by regulatory requirements internationally that only require a drug to be demonstrably more effective than a placebo, rather than more effective than an existing therapy. These modifications are then marketed heavily to doctors, and few genuinely novel drugs are emerging (Light and Lexchin, 2012). Such critics argue, in effect, that the pharmaceutical industry has evolved to try to maximise the value of their intellectual property and that most of its 'innovative' activity has little or no benefit to patients.

7.3 Innovation: a good thing

A second line of criticism of what we might think of as the 'innovation agenda' is that innovation is inherently A Good Thing (Sellar and Yeatman, 2010). Sellar and Yeatman's *1066 and All That*, originally published in 1930, is a humorous satire on English history textbooks of the time, including their tendency simplistically to classify all people and events as either 'A Good Thing' or 'A Bad Thing'. A moment's thought, however, will demonstrate that this is not so. The techniques of industrialised murder of Jews and others in the Nazi Germany of the 1940s, although innovative, cannot be seen other than as one of the most disturbing episodes of human history. Although this is perhaps the most extreme illustration of innovation creating immense harm (and no benefit), there are others where the negative consequences turn out to be world changing and not necessarily obvious initially.

For example, in the early 2000s some economists and financial commentators (e.g. Plender, 2001) began to express concern that innovation in financial instruments such as derivatives was diminishing and this would have negative consequences for the efficiency with which capital could be deployed. By 2009, however, following the turmoil in financial markets caused mostly by the complexity of financial derivatives that few could understand, the *Financial Times* reported that Lord Adair Turner, the then Chairman of the UK financial regulator the Financial Services Authority, as saying 'Not all financial innovation is valuable, not all trading activity plays a useful role, and a bigger financial system is not necessarily a better one.' (Masters, 2009). Ultimately, then, the financial innovations that had so dominated the growth of the financial sector in London and elsewhere following widespread deregulation of the industry in the 1980s turned out to have catastrophic consequences for the stability of the global financial markets and the economies of many countries more generally.

Financial derivatives are not an isolated example: the negative environmental consequences of widespread use of the internal combustion engine are becoming clearer a century after Henry Ford launched the Ford Model T car, even as the internal combustion engine continues to diffuse rapidly in emerging economies such as India and China; thalidomide, a drug used in the late 1950s to aid sleep and to treat pregnant women's 'morning sickness' proved to be the source of serious physical birth defects among their children. There are many others. This recognition that innovations can turn out to have negative as well as positive outcomes, or that the benefits and costs are spread differentially among groups in society, gave birth to the field of technology assessment (TA) which emerged in the 1970s.

7.4 So what?

We have not included this section because we are arguing that innovation is dangerous or worthless. We would not be writing the course if we thought that! Rather – and as we noted previously – we want to encourage a critical approach to some of the claims that are so frequently made on behalf of inventions and innovations. Often these claims will come from people and organisations with vested interests in promoting a particular product or way of doing things. They also come from politicians who are trying to persuade us that technological innovation is the path to future prosperity. Our overarching point is this: The study of innovation suggests that although we benefit greatly from many innovations, many others which appear important will fall by the wayside and some innovations will even prove to cause serious problems. The trajectory of any particular innovation may thus be complex and unpredictable. The organisational forms we are creating may in some circumstances turn out to inhibit, rather than promote, genuine innovation. It may even be, as Gordon (2012) has argued, that innovation may not be enough to power the kind of economic growth that we have become used to and which policy-makers are working hard to try to recapture, in the West at least. Ultimately, therefore, our purpose in raising these critiques here is to encourage a more critical understanding of debates around technological innovation.

8 Recurring and contemporary themes

In this section we provide a brief overview of some of the themes and aspects of innovation that have historically attracted – and continue to attract – attention and debate. This material builds on and extends the brief discussion of definitions and types of innovation in Section 2.

8.1 Introduction

Within the broad field of innovation, there are several recurring themes and concerns, some of which – eco-innovation, open innovation, technology transfer – will be addressed later in the course. Here we briefly introduce some of these themes to give a sense of the contemporary innovation research landscape. However, before embarking on this, and on the course more generally, a word of warning; as one researcher has put it 'the language of innovation suffers from a rich vocabulary' (Linton, 2009, p. 729). As we noted in Section 2, in the field of innovation, terminology is not always used consistently. Some terms may be disputed, and the same, or very similar, phenomena can be described in different ways. Some writers are very precise in their terminology as they try to clarify what they see as important differences in the world. The ways in which terms are used may change over time. This inconsistency in language reflects an inherently complex and multifaceted phenomenon, with features that are open to debate among researchers and practitioners.

There are two reasons for exploring this further here, however. First, it provides you with further insights into the ways in which innovation may be viewed as you work your way through this course and read more widely on innovation. Secondly, distinction between various types and aspects of innovation are important because they often reflect differences in the practices needed to encourage and sustain innovation. We also highlight some aspects of innovation (for example, social innovation and frugal innovation) that have emerged more recently as being significant. Taken together this material should therefore further supplement your ability to critically evaluate subject matter about and related to innovation and innovation management.

8.2 Degrees of innovation

In terms of economic and social consequences, every innovation is not equal. Some innovations have far-reaching, even world-changing, consequences. For example, innovations like flaking flint to make knives and axes, double entry book-keeping, heavier-than-air flight and the World Wide Web have all been associated with deep changes to the way we live. Most innovations, however, are more modest and represent largely incremental improvements to existing ways of doing things. Some inventions remain unexploited, never to become innovations.

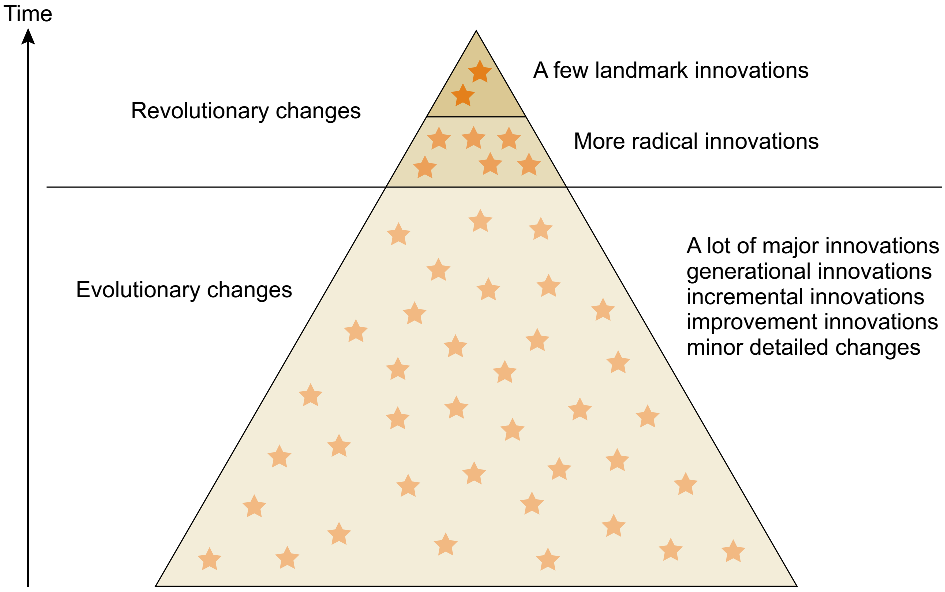

Figure 8 The iceberg of innovation

The terms used to describe different types or degrees of innovation are somewhat imprecise. One widespread distinction in the literature is between 'landmark' or 'radical' innovations with far-reaching consequences on the one hand, and the more typical 'incremental' innovations (see Figure 8). Landmark innovations are very few and rare. For example, it has been argued that the discovery of the antibiotics penicillin and streptomycin in 1939 and 1940, respectively, represented the landmark innovation of the domestication of micro-organisms and is as significant as the domestication of wild animals (Kingston, 2000). (We might argue, though, that the domestication of micro-organisms took place rather longer ago than this, as for example in alcoholic fermentation, cultures for yogurt and yeast in bread.)

8.3 Radical innovation

The term 'radical innovation' (alongside terms like discontinuous or breakthrough innovation) is used to describe innovations that have wider effects. Norman and Verganti (2012) nicely characterise the difference between incremental and radical innovation, in the context of human-centred design of information and communication technology. Routine incremental design is analogous to a blindfolded person finding their way up a hill by feeling which direction would take them to a higher point than the one they are currently on. The top of a hill is reached when every direction is lower than the current point. This 'hill climbing' type of innovation is very effective and represents the vast majority of innovative activity. The problem is, however, that the blindfolded person can never tell whether the peak they have reached is actually the highest point in the landscape.

Norman and Verganti (2012) argue that different techniques are needed to identify new hills. We might extend this metaphor still further, and think of the effort involved in descending a hill as being analogous to the costs incurred by a company which has already invested in climbing one innovation 'hill' in moving to another requiring different sets of physical, human and organisational capital. This underlines the importance of the distinction between incremental and radical innovation from our point of view in this course; the way in which incremental and radical innovation need to be managed are different.

As noted earlier, understanding the various types of innovation is complicated by its dependence on perspective. Henderson and Clark (1990) elaborated on the distinction with the example of a radical and incremental innovation (see Table 3), distinguishing between a complete product (thought of as an assembly) and its component parts. They illustrate the distinction between a room fan and its components, which include the blade, the motor, the housing and so on. The 'architecture' of the fan refers to how these components fit together. Viewed this way, innovations might be at the level of individual components, or in the relationship between components. This helps us to distinguish not whether an innovation is absolutely radical, but whether it is radical in this particular setting.

For example, the invention of the integrated circuit that makes a microprocessor might be thought of as a radical innovation in terms of its wider economic and social consequences. However, if we use a microprocessor to control the speed at which a room fan rotates, it would in Henderson and Clark's terminology be a 'modular' innovation – it completely changes the design of one component of the fan, but does not change the relationship of the control function of the fan to any of the other components – the overall architecture of the fan remains largely unchanged. Subsequent reprogramming of the microprocessor to change the way the fan operates in particular circumstances might represent an incremental innovation. Adding a motor to vary the direction in which the fan points might represent an architectural innovation, as it uses the same type of component but changes the behaviour of the functioning of the fan as a whole.

Table 3 A framework for defining innovation (Henderson and Clark, 1990, p. 12)

		Core concepts	
		Reinforced	Overturned
Linkages between core concepts and components (architecture)	Unchanged	Incremental innovation	Modular innovation
	Changed	Architectural innovation	Radical innovation

8.4 Incremental innovation

Although Henderson and Clark's approach to understanding degrees of innovation helps us to understand the significance of a technological innovation in terms of its relationship to other technologies, it remains primarily 'attribute focused'. That is, it understands the degree of innovation primarily in terms of the attributes of a particular technology, and the technological context in which it is used.

The distinction between radical and incremental innovations helps us to think not only about the attributes of a particular technological innovation but also about where the different types of innovation tend to take place. Large, established firms are (generally) less good at radical innovation, whereas smaller companies tend to be more able to make radical innovations. Much of the recent history of ICT appears to bear this out. In the 1980s, the (then) small start-up companies Microsoft and Apple responded to the radical innovation of the microcomputer in ways that larger established companies such as IBM could not. More recently, we have seen similar cases with the emergence of companies and products like Facebook and Twitter. To return to our hill-climbing metaphor, it is difficult to see how anyone would have arrived at an idea for either of these products by incrementally improving existing products; they represent rather different hills.

8.5 Disruptive innovation

This understanding of disruptive innovation happening, in smaller companies (a high proportion of which seem to be led by college drop-outs in the USA), has become something of an orthodoxy. Tushman and Anderson (1986) proposed that the differences in the innovative capacities of firms could be explained by whether an innovation enhanced or destroyed the competencies of established companies. The move to micro-computing, for example, challenged rather than supported the competency of companies like IBM, which focused on producing smaller numbers of very large computers and providing ongoing services to larger corporate customers. These were not the competencies required in the production of large numbers of lower value computers, effectively as commodities. Instead new entrants moved into the personal computer market and came to dominate it.

Christensen has come to see the term 'disruptive technology' that he had been using in his influential book *The Innovator's Dilemma* (Christensen, 1997) as misleading (Christensen, 2006). He illustrates why this is so, using the example of the Digital Equipment Corporation (DEC). DEC was the leading maker of minicomputers during the 1960s and 1970s but missed out on the growth of personal computers during the 1980s. This was not because of the technology – DEC's engineers had no problems with designing PCs – but rather because it missed out on the opportunity as a result of its business model. In the early 1980s, the company believed it could make 40% gross margin on PCs that would sell for $2,000. The problem was that proposals to develop PCs were competing for resources inside the company with proposals to make more powerful $500,000 minicomputers with a gross margin of 60%. Additionally, its existing customers for large computers were not the same customers as the likely customers for PCs, so making PCs would have brought the additional risks and costs associated with entering new markets. Given DEC's internal logic, it is unsurprising that they did not focus resources on developing the PC.

By contrast, although we might argue that wireless telephony is a disruptive technology in relation to fixed-line telephony, major US fixed line companies like Verizon and SBC responded to the potential threat by simply buying up wireless operators. The wireless customers and profit models fitted with the fixed line operators' existing business model, rather than disrupting them. For Christensen, then, it is not the technology that is disruptive, but the technology in relation to an incumbent's business model. Consequently, he no longer talks of 'disruptive technology' but of 'disruptive innovation' that threatens a firm's business model, and by contrast of 'sustaining innovation' that consolidates its position (Christensen and Overdorf, 2000). This is an argument that we would suggest anyone involved with innovation should keep firmly in mind.

8.6 Product and process innovation

When we think of innovation, we frequently tend to think of innovation in products. However, as we briefly outlined in Sections 1 and 2, innovation in the processes by which these products are made and distributed can be as important, or even more important, in generating value. Changes in production processes can disrupt entire industries, as evidenced with float glass. To introduce the process, watch the following extract from the BBC programme *Made in Britain*.

In the decades before 1960, there were two methods for making sheets of glass industrially. Sheet glass was made by pulling a ribbon of glass upwards using asbestos rollers, through a block floating on molten glass. As the glass cooled and hardened it was cut into sheets as required. This method was cheap but the glass was prone to flaws and optical distortion. Where higher quality glass was needed, for example in large shop windows or in mirrors, glass was rolled into a plate and ground and polished to produce a smooth surface, making plate glass. Plate glass was high quality but expensive to make. The two types of glass effectively comprised two separate industries, with different production plants and different customers. In 1953 Sir Alastair Pilkington, working in research and development at Pilkington Glass in Doncaster, UK, filed a provisional British patent for a new process, which became known as 'float glass'. Here, molten glass is floated on molten tin, producing very even and flat sheets. With subsequent development it became possible to produce glass of the quality achieved by plate glass but without the capital and labour costs associated with grinding and polishing, and Pilkington Glass, one of the major international glass manufacturers, replaced their plate glass process with float glass processes in 1959.

During the 1960s the process was further developed and refined by Pilkington and others, allowing the faster production of thinner sheets of glass to the point where it was becoming competitive not just with plate glass on quality, but also with sheet glass on price. In Western Europe and North America, float glass replaced both of the earlier 'industries' by the mid-1970s with a method that produced high-quality glass at low cost. Glass production had been hugely changed by the emergence not of a new product, but of a new process for making the product (Uusitalo and Mikkola, 2010).

Glass manufacture is not an isolated example of this kind of innovation. Indeed, there is a recurring pattern: after a new product is introduced to the market, there is often a flurry of associated product innovation. As a dominant product design is established, however, product innovation often diminishes as a source of value. Instead, we may see an increase in innovative activity that reduces cost or adds value in the production process (Abernathy and Utterback, 1978) as illustrated in Figure 9.

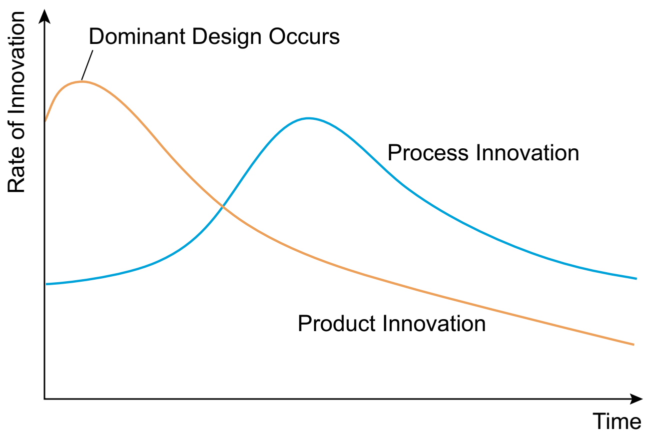

Figure 9 'Utterback Abernathy ' diagram of relationship between product and process innovation (Abernathy and Utterback, 1978)

8.7 Service innovation

The previous section identifies how value can be created by innovation in the process of making a product, rather than in the product itself. Before continuing, however, it is worth noting that innovation is also vital in service industries where the product itself may not be a material artefact. The service sector is now hugely important economically and innovation is every bit as significant to this sector as it is to manufacturing.

The service sector comprises a vast range of industries such as health care, entertainment, finance and education. A service product generally takes the form of a service function (or set of functions) that can be marketed as a commodity (as in recorded music) or provided as a public service (as in social care). They are also essentially intangible, although there is often a material component that comprises a small part of the overall value; for example, the cost of the material in a dental filling is a small component of the cost of dental care. Indeed, since the 1990s the relationship between the service function itself and its material 'carrier' has been steadily weakened by digitisation in many information-intensive service industries in a series of disruptive innovations. The market for music CDs is in steep decline as music is increasingly bought and downloaded purely online. Downloading music is a radical technological change with disruptive consequences for the business models of music companies, to which they have responded by intensively lobbying policy-makers to defend their intellectual property in novel ways. Similar dynamics are found in areas such as film, news media and education.

Since the 1990s, however, increasing attention has been paid to the differing dynamics of service innovation (Miles, 2008). For example, innovations in interfaces to the service user have seen them become increasingly self-service in many cases (think, for example, of online banking or shopping). One example of the differing dynamics in service industries is the relationship between product and process innovation, which is often reversed (Barras, 1986) when compared with manufacturing industry, discussed in the previous section. In retail grocery supermarkets, for example, there has been substantial investment in computers since at least the 1970s, to improve the processes behind the service of making goods available at competitive prices in shops. Initially, large mainframe computers were used for business functions such as stock control and accounts. During the 1980s extended barcodes began to be used to track products through the supply chain, most visibly in the final stage of the supermarket checkout. ICT was used heavily to innovate in the process of getting goods into and out of shops, but the fundamental service product had remained largely the same.

The use of ICT in service product innovation happened largely in the first years of the current century, with the introduction of online shopping. Customers of companies like Sainsbury's in the UK, Carrefour in France or WalMart in the USA can order their shopping via the internet and have it delivered to their homes. This major innovation in the service product not only followed decades of extensive use of ICT in service process innovation, but built on it. The product innovation followed the process innovation, reversing the relationship seen in manufacturing industries (see Figure 10). Barras (1986) gives similar examples in insurance, accountancy and local government.

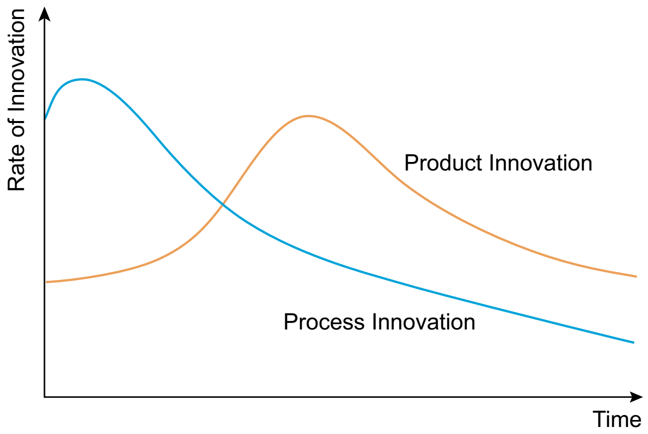

Figure 10 Barras's reverse product cycle in service industries (Linton and Walsh, 2008)

8.8 Diffusion of innovations

The extent to which an invention becomes an innovation is largely a result of the way it spreads through a population of people or organisations. This process is known as the diffusion of innovation. Again, we briefly flagged this topic in Section 1 and the fact that the study of diffusion has been heavily influenced by Everett Rogers, whose book *Diffusion of Innovations* is in its fifth (2003) edition at the time of writing (2013). Rogers identifies four main elements in the diffusion of an innovation:

- The innovation. An innovation is any idea, object or practice that is new to the would-be adopter. There are five main characteristics of an innovation that influence its uptake:
    1. Relative advantage: the extent to which it is thought to be better than whatever it replaces.
    2. Compatibility: the extent to which it is thought to be compatible with adopters' past experiences, values and other technologies. For example, the diffusion of contraception is heavily influenced by a community's religious beliefs.
    3. Complexity; the extent to which potential users find an innovation easy to understand and use.
    4. Trialability: the extent to which a potential adopter can 'try before they buy' an innovation, and hence reduce the risk of adopting.
    5. Observability: potential users are more likely to adopt an innovation if the benefits of others' use are more visible to them.
- Communication channels. Potential adopters generally find out about an innovation through personal communications and through the relevant media. The similarities and differences within people's social networks play important roles in how people get to know about and understand innovations.
- Time. Decisions about the adoption of an innovation often change over time. For example, in a competitive situation the advantages of adoption of an innovation will often be greater for the earlier adopter. The competitive advantage of using a van to deliver produce to customers would be rather higher when competitors are still using a horse and cart. Once everybody is using a van, it becomes merely a cost of doing business and there is little or no competitive advantage to be gained.

- Social structure. Diffusion happens in social systems, and this will affect how an innovation diffuses. For example, in a bureaucratic organisation where decisions on procurement are made centrally, it will be harder for an individual to adopt an innovation without official sanction.

These factors will all affect the rate at which people adopt an innovation. However, there will generally be something like a ‘bell-curve’ of people adopting a technology. Rogers uses this curve to identify adopters as illustrated in Figure 11.

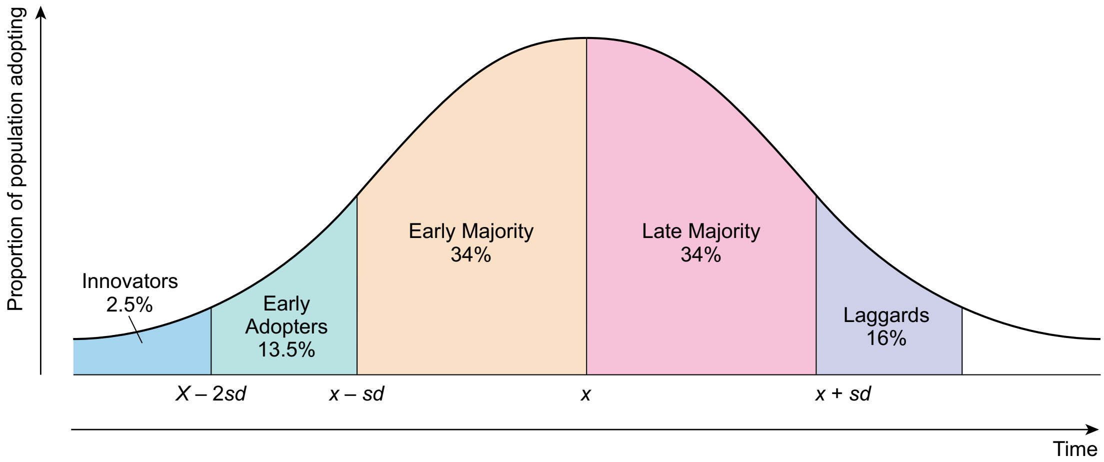

Figure 11 Adopter categorisation on the basis of innovativeness (Rogers, 2003)

8.9 Adopter categorisation

Typically, there is a small number of early adopters, and an even smaller number of what Rogers terms ‘innovators’, who are the first to adopt. (We should note that Rogers’ use of the term ‘innovator’ here to describe very earliest adopters of a technology is different from the way it is usually used to describe those who bring an innovation to market.) The experiences of these earliest adopters, and their connections to a wider population may influence the speed at which (or indeed, whether) others in a population adopt. Finally, Rogers identifies as ‘laggards’ those who adopt only after the vast majority of a population.

This pattern leads to an ‘S-curve’ of the spread of an innovation through a population (see Figure 12). The precise shape of the curve varies depending on the factors outlined above. Some innovations will inevitably diffuse more quickly than others. Others have elaborated on this, for example in the case of interactive media (Markus, 1987), where the usefulness of a telephone, email or, more recently, SMS (and software such as Skype, Facebook or Twitter) becomes increasingly useful as more people use it. This is unlike most technologies where the early adopter gains competitive advantage. These technologies, Markus argues, will either diffuse very rapidly or, if they fail to achieve some ‘critical mass’ of users, fall into disuse entirely.

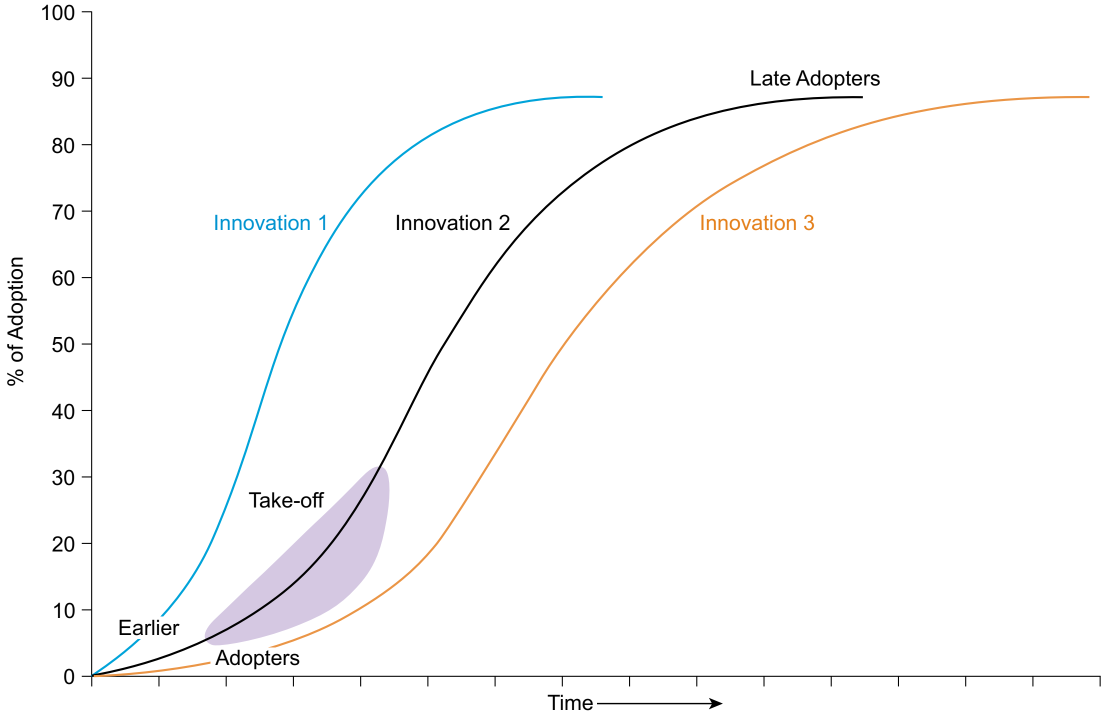

Figure 12 Shapes of curves of diffusion for innovations that spread over various periods of time (Rogers, 2003)

Some have argued that Rogers' view of the diffusion of innovation risks over-simplifying the process, reducing it to rather simple decisions of whether or not to adopt a given innovation. Rogers, they argue, views the innovation itself as relatively unchanging as it diffuses, though in later editions of his *Diffusion of Innovations* he briefly discusses the idea of 're-invention' by users. However, in some contexts at least, particularly where organisations rather than individual consumers adopt innovations, the adoption decision and its associated implementation processes can be rather more complex.

For example, 'configurational' technologies are those, like factory robotic systems, that are not bought 'off the shelf' as a standard, well-defined product but where the implementation itself might be rather messy, requiring reconfiguration and the assembly of components in new ways. Here, innovation is not restricted to the design and building phase of a technology, but happens when the technology is being installed and used in a combined process which Fleck (1994) has called 'innofusion'. Increasingly, there is interest in designing innovations precisely so that users can adapt them for use in new ways, which may then be taken up by someone else.

8.10 Putting it all together

From a management perspective, it is important to note that invention is not the starting point for innovation, but something that can be seen as the outcome of things like creativity and ideas generation, competitor awareness, and the availability of new materials or components. Chance, or luck, also plays a part, as we noted in Section 3, although as Louis Pasteur, one of the founders of the field of medical microbiology, stated in an 1854 lecture: 'in observation, fortune favours only the prepared mind'. How we organise ourselves will affect the chances of generating inventions and innovations. Figure 13 illustrates elements of an innovation strategy, and the questions we can be asking ourselves about each one.

It is difficult to produce a universal representation of the various components of the innovation process. However, Figure 13 also acts as a sketch of how these elements fit together. A new idea for a service or product will typically involve the development of one or more prototypes or pilots, and the implementation of a production process. As discussed earlier, though, an innovation might also be applied to the process of producing an existing product (a process innovation). We have also seen that, in service innovations, process innovation may precede product innovation (the reverse of the way it is represented in Figure 13). As we noted earlier in this course, innovations might also apply to the marketing of a product or service. Whatever the type of innovation, at this stage, the new idea remains as an idea or invention; it only becomes an innovation at the point at which it is used to add value in commercial or social use. As they diffuse, most innovations will enter subsequent phases of incremental innovation (again, possibly in product, process or marketing) and further iterations of development, marketing and diffusion. Eventually, in many cases, innovations will themselves be displaced by newer innovations leading to their decline and displacement.

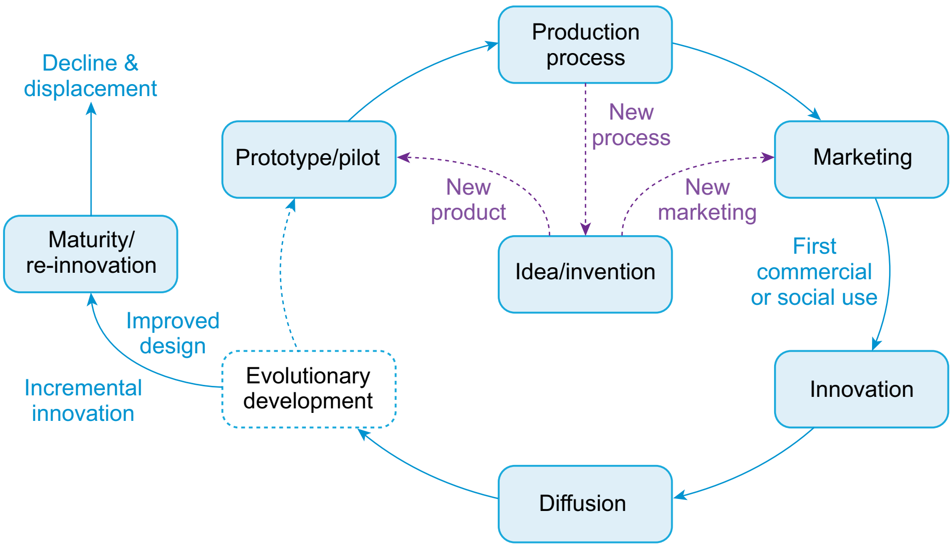

Figure 13 Putting it all together

Conclusion

This free course aimed to provide you with an overview and introduction to the range of related concepts, ideas and debates that enable you to develop a critical understanding of technological innovation and management.

Throughout this course we have linked to external resources, as well as included a range of activities, which should have served to illustrate, think through and reinforce how the various topics apply to your own situation or to one with which you are familiar. One feature of studying innovation, as distinct from the technological disciplines which generate much innovation, is that it is a fundamentally social and economic field. Consequently, similar phenomena may have different meanings or implications in different contexts: What is 'old hat' in one area of the economy may well be a radical novelty in another. Thinking about the relevance of the concepts that we have introduced to your own field, and reading about contemporary thinking and practice, will deepen your understanding of these ideas.

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Acknowledgements

This free course was written by Ivan Horrocks and Steve Walker.

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Text

Section 2.1: extract from!Warning! Tahoma not supportedOECD (2005) *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, 3rd edn, Luxembourg, OECD/Statistical Office of the European Communities.

Section 6.3: adapted extracts from Igartua, I. J., Garrigos, J.A., and Hervas-Oliver, J. L. (2010) 'How innovation management techniques support open innovation strategy', *Research-Technology Management*, vol. 53, no. 3, pp. 41–52.

Diagrams

Figure 1: adapted from Rothwell, R. (1992) 'Successful industrial innovation: critical factors for the 1990s', *R&D Management*, vol. 22, no. 3, pp. 221–39.

Figure 4: adapted from Dodgson, M., Gann, D. and Salter, A. (2008) *The Management of Technological Innovation*, Oxford, Oxford University Press.

Figure 5: adapted from Dodgson, M., Gann, D. and Salter, A. (2008) *The Management of Technological Innovation*, Oxford, Oxford University Press.

Figure 6: adapted from Dodgson, M., Gann, D. and Salter, A. (2008) *The Management of Technological Innovation*, Oxford, Oxford University Press.

Figure 7: adapted from: Tidd, J. and Bessant, J. (2009). *Integrating Technological, Market and Organisational Change*!Warning! Tahoma not supported, 4th edn, Chichester, John Wiley and Sons.

Figure 9: Abernathy, W. J. and Utterback, J. M. (1978) 'Patterns of industrial innovation', *Technology Review*, vol. 80, no. 7, pp. 40–7.

Figure 10: Linton, J. D. and Walsh, S. T. (2008) 'A theory of innovation for process-based innovations such as nanotechnology', *!Warning! Tahoma not supportedTechnological Forecasting and Social Change*, vol. 75, no. 5, pp. 583–94.

Figure 11: adapted from Rogers, E. (2003) *Diffusion of Innovations*, 5th edn, London, The Free Press.

Figure 12: adapted from Rogers, E. (2003) *Diffusion of Innovations*, 5th edn, London, The Free Press.

Table

Table 2: adapted from: Dodgson, M., Gann, D. and Salter, A. (2008) The Management of Technological Innovation, Oxford, Oxford University Press.

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