Technology

Such work often begins with a human want (for example, better safety for an Infant passenger In a car) or an aspiration (for example, o see the inside of a human artery or to land on the Moon), and technologists draw on resources of many kinds including visual imagination, technical skills, tools, and scientific and other branches of knowledge. Technological activity is as old as human history and its impact on almost all aspects of people's lives has been profound.

A common feature of technological activity, no matter what outcome Is In mind, Is the ability to design. In common with technology, design Is difficult to define briefly although the general statement that it is " the exercise of imagination in the specification of form" captures much of what is involved. The aim of design is to give some form, pattern, structure, or arrangement to an intended technological product so that it is an integrated and balanced whole which will do what is intended.

Designing often begins with an Idea in a person's mind and the designer has to be able to envisage situations, transformations, and outcomes, and model these In the mind's eye. In the 19th century James Nasty, when describing how he had invented his steam pile driver, said that the machine " was in my mind's eye long before I saw it in action"; he could " build up in the mind mechanical structures and set them to work in imagination".

Much of this thinking is non-verbal and visual; it also involves creativity, including the ability to put together ideas in new ways. Sometimes this is a solitary activity, and was often thus in the past, but many designers today work In teams where discussion, sketches, and other visual representations,

as well as analogies and ideas plucked from apparently unconnected fields, can all help the process.

One problem which designers face is that the requirements that a product has to fulfill are not always compatible: ease of maintenance, for example, may conflict with cost and aesthetic appearance; safety incinerations may not be reconciled easily with completion of the work by the deadline; and materials chosen on technical grounds for their salability may raise concerns on environmental or moral grounds (for example, waste disposal difficulties: production by unacceptable methods such as exploited labor).

Compromise and optimization are necessary when designing. Designing is sometimes represented as a linear or a looped set of processes-? starting with identification of a problem or requirement, followed by generation of ideas for solutions; selection of a promising design option is then detailed, made, and Experience from making, for instance, can feed back and lead to modifications in the design. Also, evaluation is an on-going process throughout the stages.

It is also the case that the processes of designing can differ according to the product involved. For example, designing active matrix liquid crystal displays, involving the use of basic scientific research, is different from designing corkscrews or mousetraps. Similarly, designing for manufacture on a large scale may require modifications to an artifact that was designed for use, but only as a one-off product. TECHNOLOGY AND SCIENCE

Although technology and science have many features in common-? not least in the minds of many people who link them together when viewed as

present-day bodies of practice-? their goals and how they Judge success tend to differ. In its most basic form, science is driven by curiosity and speculation about the natural world without thought of any immediate application. It aims to produce theories which can be tested experimentally in the public domain and which are valued according to criteria such as simplicity, elegance, comprehensiveness, and range of explanatory power.

By no means all that goes on under the name of science has this " blue-sky', unconstrained quality; so-called strategic science, for example, is focused more on yielding knowledge that might assist the subsequent development of, as yet unidentified, winning products and processes in the market-place. Technology, on the other hand, has the goal of creating and improving artifacts and systems to satisfy human wants or aspirations. Success is Judged in terms of considerations such as efficiency of performance, reliability, durability, cost of production, ecological impact, and end-of-life disability.

It has sometimes been said that whereas the output from science is a published paper for all to read and criticize, that from technology is a patent conferring sole ownership of the invention on the holder. For many centuries technological advances of great significance were made without benefit of knowledge from science. The notable achievements of Asian technology by the end of the first millennium AD in fields such as iron production, printing, and hydraulic engineering, including dams, canals, and irrigation systems, are well documented.

In southern Asia, at a later period, the high quality of Indian excite products, especially painted and printed cotton goods, set standards which were an incentive to technological developments in Britain. Water wheels, canal locks, barbed wire (without which the American West could not have been opened up), food preservation, fermentation and many metallurgical processes are other instances where technology ran ahead of science.

The relationship underwent change especially in the late 19th century with the growth of the chemical and electrical power industries; in these, scientific knowledge was of direct use in the solving of robbers and the development of products, although it was rarely sufficient on its own. At a later date the communications and electronics industries provided further testimony to the effectiveness of a closer relationship between science and technology, as indeed did the experience of World War II and subsequent more local military conflicts.

By the second half of the 20th century, much modern technology was intimately related to scientific knowledge, and science itself had become increasingly linked to technology through its dependence upon complex nuclear magnetic resonance imaging, a diagnostic technique widely used in decline, could not have been developed without scientific knowledge of the magnetic properties of atomic nuclei.

The symbiotic and synergistic relationship between modern technology and modern science has led some to use the term technicians to describe what they see as now an essentially merged, even hybrid, enterprise. Whether merged or not today, in the past science and technology have often followed

independent paths. Furthermore, in so far as any relationship was acknowledged, it was most frequently seen as hierarchical, with technology practice trailing dependently in the wake of scientific theory.

This notion that technology was merely applied science enjoyed wide currency in Euro-American circles, and beyond, throughout much of the 19th and 20th centuries. Today there would be little support for it. A more widely accepted model of the relationship is that of two different but interdependent communities of practice which overlap and intermeshed in their activities. However, the scientific knowledge constructed by scientists in their search for understanding of natural phenomena is not always in a form which enables it to be used directly and effectively in technological tasks.

It often has to be reworked and reinstated into a form which relates better to the design parameters involved. HISTORICAL PERSPECTIVES Historical accounts of technology can be constructed from many different perspectives, each of which may help in the understanding of this complex enterprise. At the most general level, attempts have been made to discern and characterize distinctive periods in the evolution of technology. Writing in the sass, the Spanish philosopher Joss Ortega y Gassed identified three.

In the first and longest period, there were no systematic techniques for the discovery and development of technological devices. The earliest toolmakers' achievements such as stone axes, scrapers, and control of fire were no more than the products of chance. In the second period, certain technological skills had become sufficiently conscious to be passed from one

generation to the next by accomplished practitioners. These craftsmen, however, had no systematic body of knowledge about their devices.

Possession of this kind of knowledge, resulting from analytical modes of thought associated with modern science, characterized the third period and empowered people-? in a radically different way from previously-? to realize their technological goals. Also in the sass, Lewis Uniform published his classic work Technicians and Civilization, including an analysis of the last 1, 000 years of the development of technology in terms of three successive, but overlapping and interpenetrating, phases.

The first, " etching" phase (roughly ad 1000 to 1750) was characterized by raw materials such as wood, glass, and water, with increased use of horse power and energy from wind and water. This was followed by a " polytechnic" phase (roughly 1750 to 1900) a period of " carboniferous capitalism" characterized by a coal and iron complex and the steam engine. Beyond this came a " nineteenth" phase, with science prominent and an electricity-alloy complex with new materials such as plastics coming into use.

Electrical energy and diesel and petrol combustion engines replaced the steam engine. Despite similarities, both of these analyses fail to reflect the impact of technology or the technological characteristics of the late 20th century. " smart" materials which can respond to changes around them and behave as if possessing a memory. Technology has extended into the realm of the living with, for example, genetically engineered strains of " improved" plants and animals. Nuclear power is an alternative, if controversial, energy source.

Dramatically enhanced means of communication and information processing are widely available and there has been a substantial growth of complex socio-technical systems relating to almost every aspect of work and everyday life-? such as the ones encountered at the supermarket checkout or when buying a flight ticket. The scale of these technological innovations and the speed of their implementation are quite different from anything experienced in previous phases of the evolution of technology. At the same time a extinguishing feature of the age has been a growing awareness of negative aspects of technology.

Technological disasters of unprecedented magnitude have occurred and been widely publicized: the list is long and includes spillages from giant oil tankers; the 1984 tragedy at Opal, India, when an explosion at the Union Carbide chemicals plant led to the escape of methyl assassinate and the death of over 3, 000 people, the worst industrial accident to date; the 1986 space shuttle Challenger disaster, when the spacecraft exploded Just after the launch killing seven astronauts; ND also in 1986, the Coherency disaster when a fire in the core of a Soviet nuclear reactor at Coherency' in Ukraine resulted in 31 deaths and the spewing out of deposits of radioactive debris, which fell on many regions of the world-? the world's worst nuclear industry accident. The United Nations Conference on Environment and Development-? widely known as the Earth Summit, held in ROI De Jeanine in 1992-? brought into prominence issues such as climatic change, sustainable development, and the more responsible management of global resources, with particular regard to environmental pollution, waste disposal, and a reduction in the gap in technological capacity between developed and developing countries. In

this spectacular new phase, as the 20th century closes, any characterization of technology would be incomplete if it failed to acknowledge its inescapable moral dimension.

Perhaps no other technological developments have more vividly brought home this realization than those in the field of atomic energy since the dropping of two atomic bombs on the Japanese cities of Hiroshima and Nagasaki in 1945. As Robert Oppenheim, scientific leader of the Manhattan Project which produced the original bombs, later marked: " the physicists have known sin, and this is a knowledge which they cannot lose". Less comprehensive historical studies have shed further light on the nature and development of technology. A broad distinction can be drawn between so-called internals and contextual accounts. In the internals description the focus is predominantly on the design features of the particular devices and on related matters such as the nature of technical improvements and the stimulus provided to other inventions.

Medieval fortifications, ploughs and ploughshares, keyboard chimneys, clocks, steel cantilever bridges, chain mail, steam engines, space rockets, and the mariner's compass have been, and are typical, subjects for internals histories. Informative though these are, such accounts tend to provide little in the way of explanation of why artifacts have taken the form they did and why mutations in those artifacts have occurred. In contrast, contextual accounts place by, technological developments. The economic, social, and political ambiance in which the technological activity took place and in which it assumed its particular form becomes the focus of historical investigation.

Other external factors, for example geographical, legal, and environmental constraints, may also affect the shaping of technology and, in turn, contribute to a view of technology as itself an influence on the cultural context. For example, the study of the consequences for workers in the machine-tool industry of a technological development such as automation has served to locate technology in a political context and to highlight questions about the identity and motives of the social and managerial groups who took decisions about the particular form which the technology should assume. A premise here is that there is nothing inevitable about any technological development.

It could always have been different; other options were available. The technology we encounter is the result of decisions which reflect the value judgments of those who were in a position to shape the technology. It would seem that form not only follows function, but power as well. V CONTROL OF TECHNOLOGY The extent to which technology is under human control is an important question, the answer to which has profound implications for how people perceive technology. On the one hand, there are the social constructionists who believe that technology is a LOL shaped by the bidding of its creators or, at least, that it is social groups who define and give meaning to artifacts.

A motor car is, after all, not Just a means of transport: it can be a status symbol, a reflection of self-image, a source of Treasury revenue, a criminal's machine for ram-raiding, a competitor to rail travel provisions, the basis for a manufacturing or service Job, and much more besides. On the other hand there is the view that, once launched, technology assumes a life of its own as

an autonomous agent of change, driving history. Far from being society's servant, genealogy is society's master, increasingly shaping our destinies in ways which seem inevitable and irreversible. According to believers in this technological determinism, we are progressively being maneuvered into ways of acting, both in the home and in employment, which are not of our deliberate choosing, but which are dictated by the technologies we have created. Instead of our values shaping technology, technology is shaping our values.

The motor car was not invented to support out-of-town shopping and the depopulation of city centers; air pollution by exhaust emissions as not a planned outcome; the sacrificing of tracts of countryside and areas of natural beauty for additional roads to reduce traffic congestion was never intended by the pioneer manufacturers; nor was the association of fast cars with crime. Between the poles of social constructivism and technological determinism there are intermediate positions for which historical evidence lends some support. Large, complex technological systems seem capable of developing a momentum of their own and technologies can display latent inclinations that predispose people to develop certain lifestyles rather than others. Fortunately, neither momentum nor inclination is irresistible. An example is the development of anti-pollution technology, with legislation to support it, in the case of the motor car.

What does appear to be the case, however, is that technology is not only a moral activity, but a political one as where the effects and possible impacts of technological change can be openly addressed and their compatibility with personal and society's goals assessed. VI WOMEN AND TECHNOLOGY A

remarkable feature of the history of technological development, at least as it has been written until comparatively recently, is the invisibility of women. The view that here have been few women technologists is deeply rooted and has been periodically reinforced by heroic accounts of, for example, the great road-makers, fen-drainers, canal and bridge builders, and lighthouse constructors in books such as Samuel Smiles' Men of Invention and Industry (1884).

Yet women have been growers, gatherers, and processors and stores of food from, and even before, the beginning of recorded history. In some countries their responsibilities in this respect remain unchanged today. Similarly, in many societies the activities of infant and child care, nursing, water and wood (if not child) carrying, and spinning and weaving rotationally have been, and often still are, seen as women's work. Historically, they have, worldwide, had a key role as healers and as sources of knowledge and practice relating to contraception, the premature termination of pregnancies, and the easing of labor, childbirth, and menstrual experiences. In short, women have always lived in close association with certain technologies.

It has been claimed that they were responsible for some early technological innovations such as the digging stick (possibly the first lever) and the rotary quern (a hand-operated grain mill) as the oral's first crank. The designers of other artifacts such as cradles, the baby bottle, buttons and button holes, and slings that permit agricultural work while carrying an infant remain anonymous, but the probability is strong that they originated with women. More recently, studies of the technological capabilities of girls and women in countries including the Sudan, Sir Lankan, Zanzibar, Nigeria, and the

Democratic Republic of the Congo have demonstrated the extent of their ingenuity in matters of food preparation, often in the face of great adversity.

To give Just one example, when he Tong tribe was transplanted from north-western Zanzibar to Motherland North Province (to allow the flooding of the valley of the Zambia River for the Kari hydroelectric scheme), it moved from rich alluvial soils to an area of poor soils with low rainfall, where hunting was prohibited. Because it was difficult to grow enough food, the women innovated and adapted food production and processing techniques to supplement family diets. New sources of food were identified from indigenous plants and trees, and new processes were developed for preparing food and rendering it fit for storage. In industrialized societies recent research has provided evidence of women's previously unacknowledged contributions to technological developments. Examples include the cotton gin, the sewing machine, the small electric motor, the McCormick reaper, the printing press, and the Jacquard loom.

Also, it is clear that women were rarely passive recipients of technology, but, as its users, could interact in ways which fed back into and influenced the design of artifacts and systems. The work experiences of women telephones in the first exchanges were contributory to the development of future telephone networks. There are no simple explanations for the invisibility of women in the history of technology. Possibly men, who wrote the histories, simply did not know what women and fish and then sit down; women's work is all else". For many years the inability of a woman to patent an invention in her own name was clearly an obstacle to recognition.

The need for capital to support a period of trial and development of a novel artifact was another barrier. It was only in 1882, when the Married Women's Property Act was passed, that British women acquired legal possession and control of personal property independently of their husbands. The dominant role of warfare and military concerns in the development of technology has also been suggested as contributory to women's absence from the pages of its history. There may, however, be considerations of a different kind to take into account. It has been argued that the ways in which women value things and people and communicate with others are different from those of men.

As a generalization, women are reputed to be less adversarial, more given to networking and generally less formal and hierarchical relationships, and concerned to minimize disaster and confrontation, as opposed to the authoritarian, rule-bound, competitive, and archival structures of the world of men, intent on maximizing gain. Even if these differences are more the product of socially determined roles than innate propensities, it would seem that the greater involvement of women in technology could lead to a wider definition of what counts as technological, and to possibly different solutions to what are deemed technological problems. Vile TECHNOLOGY AND CULTURE Culture is often taken to mean the norms, values, beliefs, and conventions of a group.

Members interpret their experiences in terms of these shared values and categories and so can be distinguished from members of other groups. An example is the way in which different beliefs about the origin of human life, about the relationship of humans to the natural world, and about death are held by different religious groups such as Buddhists, Christians, and

Confucian. Following from this it is suggested that technologies which originate in a particular cultural context bear the imprint of that culture. They will reflect characteristic values and beliefs as do, for example, the pyramids of Egypt, the Gothic cathedrals of medieval Europe, and the mosques of the Islamic world in their structure, configuration, and decoration.

From the present day, Kanji Eagan, designer of Yamaha motorcycles and musical instruments, has argued that Japanese design is characterized by " complex simplicity': the products are small and precision built, lightweight yet robust, energy-frugal, and miniaturized with quality-? all attributes which he regards as expressions of Japanese culture. French couture and cuisine is a further example where technological products are commonly regarded as expressions of cultural values and norms. Indeed, the definition of culture might be extended to include technology as a part of culture rather than a reduce of it; that is, culture comprises artifacts and technical processes as well as values and beliefs. A Technology Transfer One striking way of bringing into relief the values embedded in technologies is by their transfer from one cultural context to another.

When, in the 19th century, agricultural settlers began to invade the Canadian plains on which Indians hunted buffalo-? the mainstay of their life-? the Indian response was well captured in the You ask me to plough the ground. Shall I take a knife and tear my mother's breast? Then, when I die she will not take me to her bosom to rest You ask me to cut grass ND make hay and sell it and be rich like white men, but how dare I cut off my mother's hair? T. C. Mclean, Touch the Earth: A Self-portrait of Indian Existence The

attempt to persuade the Plains Indians to adopt the agricultural practices of plugging, planting, and harvesting brought into conflict two contrasting value systems regarding the relationship of humans to their environment.

The traditional Indian way of life involved respect for, and harmony with, nature and with the spiritual powers believed to inhabit all living and non-living things. The impact of agricultural technology as brought by the predominantly European homesteaders exulted in confusion, strain, and often the destruction of the Indian lifestyle. Not all technology transfers have had the same disastrous consequences for the recipient culture, although there are many instances where the adoption of a new technology has caused major changes in employment patterns and social structures. Change in the means of manufacturing sandals in North Africa is a case in point.

In one region the sandals were made by some 5, 000 artisan shoemakers, using local supplies of leather, glue, thread, hand tools, tacks, wax and polish, fabric linings, laces, wooden lasts, and card boxes. Then, two Swiss plastic-injection molding machines for the manufacture of sandals were introduced, each in operation for three shifts per day and requiring a labor force of only 40 workers. A million and a half pairs of sandals per year were produced, selling at less than the cost of the leather sandals and with a longer life. As a result, many indigenous small industries declined, as did employment opportunities; there was an increase in dependency on imported plastic, spare parts for the machines, and maintenance services-? all requiring foreign currency.

An accompanying increase in migration from rural areas o cities contributed to the creation of a " dual society'. Such experiences of transfer testify to the non-neutrality of technologies and the way in which they can recreate, in a new host culture, aspects of the social system of their place of origin. For this reason, technology has sometimes been likened to a social gene which can carry encoded social relations from one context to another and replicate them there. When Japan was modernized after the Meijer Restoration in 1868 and deliberately recruited science and technology experts from already industrialized countries, it sought actively to avoid the introduction of foreign values with the technologies it imported.

The cry was for " Western techniques but Eastern values"; the assimilation of new technologies was carefully managed to ensure their alliance to an intense patriotism and to the growth of the nation's industrial and military strength. Although one- way technology transfer can act as a powerful alternative to military colonization and a means of fostering the long-term dependency of the recipient culture on the provider of the technology, the transfer process is often more complex and interactive. For one thing, technologies are not used by every culture in exactly the same way. Gunpowder, invented by the Chinese and used by them for fireworks and primitive guns, when brought to Europe stimulated the production of much more powerful and devastating cannon.

Nearer the present day, a project undertaken by rural villages in India began by using cast-iron copies of farmstead pumps from the United States and Europe. While adequate for a single household, these were not designed to withstand continual daily use by an entire village community. Breakdowns

were frequent. As a result, attempts were made to design a more liable pump appropriate to the particular demands of village use. The stringent design criteria included low cost, durability, easy installation, maintenance and repair, and ability to be mass-produced under Indian conditions. However, the production of such a pump by no means solved the problem.

There was also need for a supporting infrastructure of warehouses for spare parts, distribution networks for delivery of supplies, and training programmer for those who would monitor the quality of the water supply and keep the pump in good working order. Progressive decentralization of responsibility for the technology, from government and international agencies to local manufacturers and suppliers, was needed and a system of quality control involving the standardization of pump parts brought into being. Only by the well-synchronized functioning of all components of the system, in which the pump as artifact was itself enmeshed, was the technology likely to be successful. The drilling of water boreholes and the construction of appropriate pumps represented only one component of the total challenge of transfer.

B Appropriate Technology The idea of a technology being appropriate in the sense of respecting the needs, sources, environment, and lifestyles of the people using it came into prominence in the sass. A powerful advocate was the economist E. F. Schumacher, who in his book Small is Beautiful (1973), wrote of " technology with a human face" and used the term " intermediate technology'. Schumacher drew on the belief of Gandhi that the poor of the world cannot be helped by mass production, only by production by the masses. His prescription for intermediate technology required it to make use

of the best of modern knowledge and experience; be conducive to decentralization; be compatible tit the laws of ecology; be gentle in its use of scarce resources; and serve humans instead of making them the servants of machines.

However, not all those in the so- called developing world are content to see the cultivation of appropriate technology in their own countries while the industrialized societies are perceived as speeding towards a different and high-technology future. It is clear that technology's impact on society has been profound, and never more so than today. For many, including governments, its ability to contribute to wealth enervation and economic development makes its encouragement a national priority. In the United Kingdom, a government White Paper published in 1986 asserted that " Survival and success will depend on designing, making, and selling goods and services that the customer wants at the time he wants and at a price he is prepared to pay; innovating to improve quality and efficiency; and maintaining an edge over all competition".

Subsequently, a Technology Foresight Programmer was begun to identify ways in which government resources might best be directed in the interests of the economy and to indicate areas of technology which might yield productive innovations. A series of technology foresight themes was drawn up under headings and communications, cleaner world, modeling and impact, and control in management, the latter including security and anti-fraud technology. Clearly, technology is seen as having a major role to play in improving the nation's economic competitiveness and quality of life. Similar dispositions towards, and expectations of, technology are to be found

in many other countries. The idea that the artifacts of technology are indices of progress is deeply entrenched in many societies.

For most of the industrialized world a return to a situation without electricity and water services, telephones and televisions, refrigerators, washing-machines, cars, trains, airplanes, and sewage and waste disposal systems would be widely considered to be utterly retrograde. Equally, the vision of progress for many in poorer countries has been in terms of what, technologically, others have but they have not yet got. Either way, however, what is sometimes forgotten is that technology can lead a double life; it may conform to the intentions of its creators, but it can also yield unintended, sometimes unimagined, outcomes. Even with a clear vision of what hype of society is being sought, technology can be an unpredictable ally.

It also has the ability to usurp, or divert attention from, consideration of the outcome, the onward quest for technological development itself becoming the goal. With the increased use of technology in production and service industries, a concern has grown that Jobs will be destroyed and a vast army of unemployed will result. It is true that, over the past 200 years, many millions of manual workers have been replaced by machines, most dramatically, perhaps, in agriculture. Nearer the present, much factory work has also been automated. Machines saved on labor costs while increasing production, and were thus welcomed by factory owners. However, expansion of the service sector has provided alternative employment for many.

Now, with the growing automation of service Jobs, and technological developments such as computer diagnosis of illnesses, which put even the

skilled at risk of redundancy, concerns have heightened about unemployment. Recent studies, however, provide little support for the view that technological change is the sole cause of unemployment. Rather, it is possible that technology can create more Jobs than it destroys. However, a clear picture may be difficult to obtain for some time because firms take time to learn how to use new technology effectively and replace obsolete management structures. Nevertheless, Jobs such as programmer, systems analyst, network manager, database architect, computer operator, and computer repair technician were unheard of only a short time ago and are now among the fastest growing.