SCIENCE, TECHNOLOGY, AND HUMANITY

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1 Technology is a key element of life

"*Technology can be most broadly defined as the entities, both material and immaterial, created by the application of mental and physical effort in order to achieve some value. In this usage, technology refers to tools and machines that may be used to solve real-world problems. It is a far-reaching term that may include simple tools, such as a crowbar or wooden spoon, or more complex machines, such as a space station or particle accelerator. Tools and machines need not be material; virtual technology, such as computer software and business methods, fall under this definition of technology" (from http://en.wikipedia.org/wiki/Technology).*

The burden of this chapter is to point out the fundamental importance of technology in human life, and so how any thoughts about the future of humanity must consider the nature and control of technology as a fundamental factor.

Technology has transformed our lives, and is still doing so at an ever increasing pace, reaching every aspect of living (Philbin 2003, Challoner 2009). Consider the following aspects of technology:

- language, writing, printing
- fire, wheel, clothes, shelter, hunting, agriculture
- water, sewerage, electric power: heat, light, engines
- stoves, fridges, washing machines
- tools, hardware, implements, machine tools
- transport, buildings, roads, bridges, dams
- communications: phone, fax, radio, TV, cellphones, Ipods
- medical: medicines, surgery, genetics, neurology
- information technology, computers, the internet

Some animals have quite sophisticated forms of technology (Turner 2000), but it is essentially the advanced nature of our technology and its symbolic foundation that distinguishes humans from other species; *inter alia* we are the `symbolic species' (Deacon 1997), with spoken and written language as our most important abstract technologies because they enable high level thought and planning, and indeed shape the mind through a process of co-evolution and development. However they could not function without fundamentally important social, economic, and political abstract technologies that are embodied in language (such as social roles, the power of money, property rights, and the legal system in a society). technology is not just a background to the way we live our lives: rather it is a major factor affecting all aspects of individual and communal lives; it is an omnipresent feature of our lives that shapes the way we work, play, live, think, and how we interact with each other (Kranzberg and Davenport 1972). Thus it has an enormous impact on daily life, and causes change at an ever increasing rate.

It is clears that technology not only changes the possibilities open to us, it shapes the way we think. It shapes culture to a major degree, while culture also influences technology, within the limits of what is scientifically and technologically possible.

Indeed the rise of civilisation is based on the development of technology, firstly based in science, but secondly also of an abstract character.

The key features of technology are firstly its cumulative nature: each further step depends on the one before, and is impossible without it, secondly its dependence on a core of technologically capable people who set the system up and then keep it running, and thirdly its long-lasting international character. Once a discovery is made (fire, agriculture, the wheel for example), it is there for ever after, and is adopted by all advanced societies. It outlives all the pomp and ceremony of kings and empires.

But any technology can be used for good or for ill. The dark side is environmental destruction and mass warfare enabled by technology. There is as a result a widespread fear of technology, often associated with irrationality: a lack of appreciation of its enormous positive side. Key issues are,

- ***What kind of purpose is it used for?***
- ***Who benefits? (haves and have-nots)***
- ***What are its beneficial aspects?***
- ***What are its costs?***
- ***Who will control it, and how will this be done?***

These issues arise in each domain where technology has a significant impact. There will be commonalities across these domains, as well as differences. We need to regard technology as a positive force in need of direction, across all these domains. In the following I pursue this in two parts: first considering in more detail the role of technology in society and civilisation; then, the conditions for the appropriate development of technology.

2 TECHNOLOGY AND CIVILISATION

Jacob Bronowski in his classic BBC television series *The Ascent of Man* (Bronowski 1976) charted the rise of civilisation as a concomitant of the development of technology.[1] In order to consider the future of this influence, one must catalogue the major areas where technology has had a significant influence; these are the areas that future planning needs to take into account. To consider them in detail would take volumes; I here just list them, with some brief comments.

2.1 Infrastructure of life:

Basic to the development of all higher order activity is the infrastructure of civilised life. This is the foundation for all the rest. It includes

- Water supply, waste water disposal, sewage disposal, waste disposal
- Electricity supply, other energy supply (e.g. gas)
- Transport: bicycles, cars, buses, lorries, roads, rail, ships, air travel
- Housing: structure, services, finishes, furnishing, fabrics
- Agriculture and food: farms, ranches, forests, fishing, markets, biotechnology

[1] This is in stark contrast to Kenneth Clark's BBC TV series of the same era, which ha called *Civilsation*. For Clark, civilization means just Western European art. He simply does not understand the foundations on which civilization in all continents arises.

- Tools, machine tools, construction, manufacturing, industry
- Medical and health systems: medicines, antiseptics, antibiotics, dressings, surgical instruments, CAT scanners, lasers, etc
- Security: fences, gates, locks, keys, codes, surveillance tools, weapons

These are the basics on which the rest is built.

2.2 Technology and daily life

Technology has transformed the drudgery of household and daily life.

- Hot and cold running water, water borne sewerage
- Lighting, heating (fire, electricity)
- Stoves, fridges, canned foods, frozen foods, pots, pans, knives, eating implements, tableware
- Clothes: material (fibres, cloths, colouring agents), design
- Cleaning equipment: soaps, vacuum cleaners, washing machines, dishwashers
- Entertainment: musical instruments, music systems, cinema, tv, theatre
- Leisure: playing cards, board games, balls, bats, sports shoes, playing fields, score cards, video games
- Markets, shops, commerce and advertising

2.3 Abstract technology

A key feature of technology is that crucial aspects are abstract: that is while they will eventually be embodied in material entities, their key nature is non-physical. They underlie social, economic, political, and legal systems, and centre round symbolic systems (Deacon 1997). They enable sensible organisational structure and control (Pugh 1975, Handy 1976, Beer 1978), in a way that may or may not be enhancing of humanity (Illich 1973).

- The essential basis is language
- The technological and commercial basis is mathematics
- The basis of economic transactions is money, accounting, auditing
- The basis of planning is theories and models, plans, to-do lists, timetables
- The shape of what is done is embodied in policies and associated indicator systems
- The nature of what is done is regulated by rulebooks, constitutions, laws and regulations

2.4 Technology, information, learning

Information technology now ubiquitously permeates all the other aspects of technology, transforming them all, particularly through digital computer systems based in transistors, integrated circuits, CDs, and digital memory systems, enabling information systems allowing sophisticated control of government and business (Anderson 1989) and modelling of environmental systems (Cartwright 1993). Global information and messaging networks lead to a new level of consciousness, because of almost instant awareness of events across the globe and sharing of views and information.

- Writing, paper, pencils/pens, printing, books, ebooks
- Money and banking: Bar codes, internet banking, ATMs
- Communication: Telex, Radio, Telephones, faxes, cellphones
- Images: Photography, photocopiers, films/movies, TV, global news networks

- Computers (hardware and software), computer networks, email, the world wide web/internet, Google, Wikipedia, Facebook, Youtube
- Global positioning system (GPS)
- Remote imaging from aircraft and satellites: weather, crops, fires, ocean temperature, etc

These are all becoming integrated into each other so that the boundaries between them are becoming blurred.

3 TECHNOLOGY AND HUMAN BEINGS: Usability and design

All technology is designed: houses, offices, cars, planes, computers, roads, cities, etc. as listed above are all the product of a design process. Each element has been specifically planned by someone. The way this design is done crucially affects the quality of living in the environment so created (Papanek 1974, Faimon and Weigand 2004; Garratt 2004), in particular at home on the one hand, and at the work place in the other; but also for example in whatever form of transport used to get form the one to the other ands indeed in the overall urban environment created.

It must of course be designed to do well the work it is designed to do. This arises first as regard function, and then as regards appearance. There are strong constraints on what is possible (Vogel 1998) and these must be understood and handled properly. Reliability is crucial, and simplicity should be aimed at as far as possible. There is a potential tension here between aesthetic design and functionality, and various approaches have been taken to this over the centuries: at the one end claiming that high level functionality per se inevitably *is* the core of good design, and the technical means should be dominant in design, to others with a major emphasis on style and aesthetic quality, even to the extent of being dominated by fashion, with the technical aspects being fitted into this aesthetic framework. How this works will vary greatly across all the application areas of technology: in the case of a hammer or screwdriver, function appropriately drives all; in the case of a car or building, other elements enter. A key feature here is that there are no reliable rules as to what is good design: there are guidelines and heuristics, but in the end this is where the craft of the designer is crucial. It is interesting here to look at the technology used by animals to attain their needs: what they can do is limited but sophisticated (Gould and Gould 2007).

Two specific features are worth mentioning here. First, there is the issue of the suitable kind of technology to use: when is a low tech approach adequate and when is a high tech approach more suitable? The idea of *appropriate technology*[2] is key here (Schumacher 1999): the right choice is the right level of sophistication to handle the job at hand, as far as possible using local materials and abilities to create and support the technology, rather than importing materials and methods form overseas that will probably fail and fall in to disuse after a while (Schumacher 1999, Burdick and Lederer 1958); political issues will intrude (Dickson 1974). It is also key to note that any technology has partly a hardware nature (the item itself: a stove, computer, tool, whatever) and partly a behavioural component: how you have to interact with it to get it to succeed. Hi tech products can be very difficult to use, or very easy to use, depending what they do and how they are designed. There is a trade-off between requiring the user to adapt to the technology, or making the technology adapt to the

[2] http://en.wikipedia.org/wiki/Appropriate_technology.

user. Sometimes the complexity of the user's interaction with it is unavoidable (e.g. a fighter aircraft) but sometimes it is not (e.g. in home computer systems). The designer can make crucial choices here, determining how easy it is to adapt to a new technology and make it fulfil what you want it to do.

Crucial here is the issue of the user interface: the design of the handling or control of the technology. Some devices are notoriously difficult to use, a classic case being home video recorders, and another being typical office telephone systems (such as the one at my university). The options made available to the user need to be carefully thought out, and the way decisions are made by the user structured transparently so that use if intuitive and easy. The ideal is that you can use it without needing to read a massive user manual: it should be obvious what to do next, because the options available are presented in a clear transparent way (in a motor car for example, it should be quite obvious how to turn the lights and the windscreen wipers on and off).

Great strides have been made here for example as regards computers, with the transition for a command line system suitable only for techies to use of a desktop with icons allowing selection by pointing and clicking, and drag drop and capabilities as well as clearly structured menus offering alternative ways to achieve the desired aim. The aim is to in the end have largely invisible computers (Norman 1999), with the interface adaptable to individual needs, allowing enough choice but not too much. An advanced system will recognise the need for emotional design (Norman 2004): our interaction with the technology in the end has a crucial emotional component, and if we are to be comfortable with it, this needs to be handled right (for example, kit should above all avoid leading the user to a dead end where no viable options are presented to her)

The design choices in the end embody an underlying set of values. This is such an important topic that I will now discuss it separately.

4 TECHNOLOGY AND VALUES/PURPOSE/MEANING

In the end, the key question regarding technology is what is it all used for? Who will benefit? It has immense powers that can be used for good or for bad. Some technologies are purely destructive (for example weapons production and support) although some will claim that this negative aspect is necessary for a greater good (the just war kind of theory). In the case of napalm that argument is exceedingly thin. However most technologies are neutral: they can be used for good or bad. It is a political and social choice that has to be made, embodying values in technology choice, design, and use.

4.1Access to technology

The first key issue is access to technology: how to make its benefits available to the poor as well as the well off. This is partly simply a political decision as to how to allocate resources (electricity, water, waterborne sewerage, computer and internet access) but with major economic aspects: so all the usual political debates come up here as to who controls resources and how they choose to use that control Perhaps the most enabling thing that has happened in this regard in recent decades is the spread of cellphone access to impoverished communities worldwide. Projects such as the

Grameen bank (Yunus 2001) have the potential to help greatly here, because the access to capital is crucial, as is the understanding of the nature of capital (Hawken, Lovins, and Lovins 1999).

But there is also the issue of technological knowledge: how to control it and use it, including how to repair things when they are not working properly. So technological equity cannot be separated from the major issue of educational access and quality, particularly as regards mathematics, science, and technology subjects. I will not rehearse these old debates here, except to make the remark that there is the potential for high technology access, particularly computer systems, to help developmental leapfrogging: by making world wide knowledge instantly accessible one has the potential to empower the poor and make individual learning possible for those with initiative. To enable this, computer access must be available in these communities, perhaps through schools, libraries, or community centres. There is clearly much that can be done in this regard. One needs many community projects as well as academic and industrial development.

The crucial issue then is equity: spreading the benefits and opportunities to create access for all, particularly those in less developed countries. Many issues arise in making this happen, including hardware issues (computers and memory devices, optical fibre lines and broadband communication links), software issues (making access affordable, for example through the open access movement), and capacity issues (training in how to make it all work and to maintain it). Here we need a determination to make it happen, with the privileged countries assisting the less privileged ones in all these aspects.

The second issue is the effects on employment and livelihoods once IT infrastructure is available: it has good aspects (much improved information access and productivity) and bad ones (in many cases creating unemployment). Each country needs a sensitive engagement with these issues, and the political hot potato: to what degree should this be left to free enterprise and to what degree steered by the state for the communal good. The tendency is most countries is to just let this take its course, particularly as much of the development is powered by multinationals; but it must be possible to design computer applications to support labour intensive employment as well as labour saving systems. Both are need in the right context; the state can encourage employment creation uses through suitable incentive systems.

4.2 Technology and environment

The major issue concerning technology and values that is grabbing attention at present is environmental damage due to thoughtless use of technology, including pollution of all kinds, resulting in global warming. There are many innovative options possible as regards energy technology (Lovins 1977).There is plenty of evidence that large scale energy use and associated pollution is leading to drastic climate change (Houghton 2009). This is not the place to go through the details of that debate, which of course has major political overtones and associated disinformation campaigns.

I will just make one remark here. It is my opinion that campaigns carried out under an "environmental" banner against nuclear energy and biotechnology have been positively destructive in their effects. They seem to have been carried out in such a way as to satisfy the motional needs of the protagonists rather than truly benefit either

the environment or the poor. Certainly some in these campaigns have not hesitated to use untruths to support their agendas, for example labelling GMO foods as dangerous to health – a demonstrably untrue statement. They have not been willing to consider the possibility that nuclear power is a better option than the huge damage caused by coal and oil fired power stations – as fro example James Lovelock has now stated.

What is desperately needed here is to back off form this kind of environmental fundamentalism and embrace the more moderate kinds of views proposed in Baxter (1974), where one takes into account the employment needs of the poor as well as the welfare of animal species. At present one can state with confidence that whenever any scheme is proposed that will create employment for the poor, their will always be some environmentalist who will say it should not be done; but the greatest threat to the future of South Africa is unemployment. This fact must be seriously taken into account in these decisions. Another example is the way that the long delays associated EIAs are the single major factor making provision of adequate housing for the poor almost impossible, because land cannot be released for this purpose without huge delays. More moderate regulations are needed.

4.3 Technology and democracy

On the positive side, there is a major enabling role for technology in terms of enabling democracy: providing information, allowing new efficient voting procedures, allowing efficient public consultation on key issues, and so on. It is again political will that is required to get this right, to provide the environment in which this free information flow can take place.

But of course there is also a repressive aspect of technology such as its use to suppress freedom in many coercive ways. Prisons for example are needed, but how should they be designed? How can the technology of the justice system help produce better people, for example by supporting restorative justice?

4.4 Technology and education

It has already been mentioned that high technology has the potential to assist learning to take place in a creative way, but through making all kinds of information available via the internet, and through more specific learning programs and tutorials aimed at specific targets (mathematics, science, learning a language for example). These should carefully take cognisance of the way learning takes place (Vygotsky 1978) and shape the interactions with the learner accordingly.

A comment is relevant here. There is of course a good deal of nonsense out there on the internet, as well as good information. What is lacking is a impartial quality assessment system for information on websites. This is a major lacuna, but it would be difficult to implement for obvious reasons. Nevertheless something of the kind should be tried, at least for academic subject.

4.4 Technology and crime

One important aspect if use of technology both by criminals and by police/authorities. Both sides are using increasingly sophisticated technologies, and there is certainly much that can be done on the side of the law to counter criminal activity, for example surveillance systems, and development of weapon detection systems at a distance for handguns and other small arms. This should certainly be possible if engineers tackle it

with determination. The other side of the coin is to set up a regulatory environment that will enable use of such items without abuse.

A specific issue of relevance here is the unwillingness of those responsible for the internet to tackle internet crime and spam, as well as virus writing. The phishing and fraudulent prize offers would simply die away if emails were charged for on a reasonable basis: say free for the first 300 emails per day, a small charge thereafter per email. This is certainly possible. And it is a scandal that there are websites that provide virus writing kits for free - limitations on internet abuse should surely be able to ensure that these get closed down as fast as they appear.

4.5 What values to choose?

So what values should one choose? I cannot do better than to refer to the Charter for Compassion initiated by Karen Armstrong, see http://charterforcompassion.org/site/:

In full it reads,

CHARTER FOR COMPASSION

The principle of compassion lies at the heart of all religious, ethical and spiritual traditions, calling us always to treat all others as we wish to be treated ourselves. Compassion impels us to work tirelessly to alleviate the suffering of our fellow creatures, to dethrone ourselves from the centre of our world and put another there, and to honour the inviolable sanctity of every single human being, treating everybody, without exception, with absolute justice, equity and respect.

It is also necessary in both public and private life to refrain consistently and empathically from inflicting pain. To act or speak violently out of spite, chauvinism, or self-interest, to impoverish, exploit or deny basic rights to anybody, and to incite hatred by denigrating others—even our enemies—is a denial of our common humanity. We acknowledge that we have failed to live compassionately and that some have even increased the sum of human misery in the name of religion.

We therefore call upon all men and women ~ to restore compassion to the centre of morality and religion ~ to return to the ancient principle that any interpretation of scripture that breeds violence, hatred or disdain is illegitimate ~ to ensure that youth are given accurate and respectful information about other traditions, religions and cultures ~ to encourage a positive appreciation of cultural and religious diversity ~ to cultivate an informed empathy with the suffering of all human beings—even those regarded as enemies.

We urgently need to make compassion a clear, luminous and dynamic force in our polarized world. Rooted in a principled determination to transcend selfishness, compassion can break down political, dogmatic, ideological and religious boundaries. Born of our deep interdependence, compassion is essential to human relationships and to a fulfilled humanity. It is the path to enlightenment, and indispensible to the creation of a just economy and a peaceful global community.

If these can be made the guiding values, then all else will follow.

5 CHOOSING AND SHAPING THE TECHNOLOGY OF THE FUTURE

In order to shape technology as a positive force in society, one needs to choose what aspects will be encouraged as per all the options above (and more), and then create a technologically enabling environment. I will briefly mention some issues here.

5.1 Enabling technological development

Technology has its basis in science, and in particular physics and chemistry, which determines what is possible and what is not (Bloomfield 2008). However any scientific proposal for a new technology needs a long process of development, in order to lead to production. It is a long way from idea to reliable use. One needs to develop and maintain a basic scientific infrastructure but also the technological skills associated with its development to a usable stage.

Thus the first sine qua non for it successful development is a sound basis in scientific and mathematics education. Probably the best way to go about this is to develop specific technology schools that aim to attract children interested in these areas and develop these skills through suitably skilled talented and dedicated teachers. This needs to be built on at tertiary institutions which develop specific technological and scientific skills as part of a National System of Innovation encouraging suitable students through scholarships and support right up to the post doctoral level. In principle South Africa has such a system; in practice the real weakness is at the school level, as is well known. Only the political determination to tackle entrenched power structures that protect teachers from behaving responsibly will solve this issue.

One then needs the specific structure that supports technology development. This includes availability of adventure capital for good proposals, plus the overall basis of support infrastructure required: tools, equipment, supplies of good quality materials, and above all trained technicians in the relevant areas. It is crucial to recognise here how technological infrastructure is cumulative: one needs high tech measuring and manufacturing instruments that are used to manufacture even more high tech instruments, and the knowledge base in physics, chemistry, computing, biotechnology, and other relevant areas. International involvement and exchange is crucial in keeping up to date with developments in all these areas, so nowadays a really good internet linkage is crucial for making this all happen. And then one needs a suitable environment in terms of intellectual property rights: to motivate those who make the most innovative developments, they must know that their ideas will not immediately be taken away form them once they become public.

In developing suitable technology, one needs developmental work aimed at specific areas of need; energy, water, transport, and so on, leading to specific product oriented development, but one also needs underlying basic research. It is crucial to realise here that the most fundamental technology is a by-product of blue skies research aimed simply at understanding the way things are. Nuclear energy for example came about through Einstein's efforts to understand the nature of space and time – not because he was looking for a new way of providing energy.

Thus one needs a sound process of planning and designing and part of a process of development, involving problem analysis, generating ideas, developing products in consultation with users, and testing the outcome in terms of reliability and user

friendliness. Items made need to be design for ease of construction, maintenance, and repair, if they are to be of lasting use. Production quality is of course crucial, so a [process of quality checking is vital. Then there is the issue of sales and distribution, and after sales support through a maintenance network with sufficient spare parts and qualified technicians who will handle servicing and repairs. It is a complex system, requiring care and strong support: but the benefits are enormous.

Underlying this one needs a developmental process that can handle complexity through an incremental evolutionary process, rather than being based in simplistic domineering visions that attempt to create complex systems in a single step. As in the case of architecture, see Alexander (1979), satisfactory designs evolve over time through development and use with feedback from the users playing a key role in the process. There is no shortcut that can replace painstaking patient attention to detail in design and development, understanding the way complexity arises and can be handled (Simon 2001). Nature took billions of years to achieve the design of living beings, through a series of extraordinary technological innovations (Lane 2009). We can learn from that process.

5.2 Control of and Shaping technology

So who decides what will be created? How is it supported and regulated? One needs a delicate balance between government support and individual entrepreneurial development that makes an enabling environment and encourages innovation. There needs to be some kind of overall framework that supports sound choices of purpose and values, shaping of technology in a way that brings positive benefits to society. Central control will not achieve this, bit central support for individual vision can do so. The tension between private and public control is unavoidable. The Government needs to provide support in such a way that the poor benefit as well as the rich. Local Government is key in this regard: they handle provision of infrastructure of local communities. They must have the needed capable technical staff who will handle this in a competent way.

The overall intellectual ambience in which this occurs needs to be one where usability and the human interface of high tech equipment is regarded as a key priority, As mentioned above, the focus should be on appropriate technology, whether this is high technology or not. In this country, that means that a key requirement should be where possible to increase rather than decrease employment, with unskilled as well as skilled personnel being part of the mix. The National System of Innovation must take the needs of the poor as well as the rich into account. The usual perplexities of how to assist wealth creation abound (De Soto 2000).

5.2 Priorities: Possibilities and key issues

One can't do everything, so one has to select what is most important from the viewpoint of government support. In coming decades, water and energy will be the most pressing issues, as well as access to the worldwide computer network. The greatest opportunities will be in genetics and biotechnology on the one hand, and in developments to do with understanding the brain and neuroscience on the other (Edelman 2006), particularly as regards its educational implications. Generally there is a major information-based transformation of society taking place as regards work, domestic life and leisure: this is where the greatest opportunities will arise.

This development requires access to the crucial technology such as brain scanners, scanning electron microscopes, X-ray diffractometers, laser systems, and so on: government support for such instruments is crucial. Information and computer systems of course will underlie this, so developing ability in digital systems and microelectronics is crucial.

Finally, one must not neglect here the development of abstract technologies that shape the way we think and act. The most important here are the tools and methods we use for transforming the goals of society into the choices we make (Beer 1978). The crucial aspect here is the indicators we use for societal development, that shape the resource choices we make. Is it adequate for example to use GDP and inflation rates as indicators of success of policy, or can better human development and quality of life indicators be found? Choice and implementation of societal indicators that truly relate to human welfare and development in the framework of sound values may be one of the most important investments we can make. This requires conceptual clarity as well as data collection and analysis of sound quality, providing us with the best indicators we can get for our current state and future trajectory.

Overall the message of this chapter is that we should be aware of the central and transforming nature of technology, and keep it in mind in this project of looking to humanity on the future. This paper does not claim to do anything more than point out the importance of this agenda item, and propose some issues for consideration.

REFERENCES

1. Christopher Alexander (1979) *The timeless way of building* (New York: Oxford University Press)
2. R G Anderson (1989) *Business system*s (M&E Handbooks; business and management)
3. William Baxter (1974) *People or Penguins: The case for optimal pollution* (INew York: Columbia University Press)
4. Stafford Beer (1978), *Platform for change* (Chichester: John Wiley)
5. Louis Bloomfield (2008) *How Everything Works: making physics out of the ordinary* (New York: Wiley)
6. Jacob Bronowski (1976) *The Ascent of Man: A Personal View* (Little Brown & Co)
7. Eugene Burdick and William Lederer (1958, re-issued 1999): *The Ugly American* (W.W. Norton & Co)
8. Timothy J Cartwright (1993) *Modeling the world in a spreadsheet: Environmental simulation on a microcomputer* (Baltimore: Johns Hopkins)
9. Jack Challoner, *1001 Inventions that changed the world* (Cassell Illustrated: 2009).
10. Terence Deacon (1997) *The symbolic species: The co-evolution of language and the human brain* (London: Penguin Books)
11. Hernando De Soto (2000) *The mystery of capital: why capitalism triumphs in the west and fails everywhere else* (New York: Basic Books)
12. David Dickson (1974) *Alternative technology and the politics of technical change* (Glasgow: Fontana)

13. Gerald Edelman (2006): *Second Nature: Brain science and human know*ledge (New Haven: Yale University Press)
14. Peg Faimon and John Weigand (2004) *They Nature of Design: How the principles of design shape our world – from graphics and architecture to interiors and products* (Cincinatti: HOW Design Books)
15. James Garratt (2004) *Design and Technology* (Cambridge: Cambridge University Press)
16. James L Gould and Carol Grant Gould (2007) *Animal Architects: Building and the evolution of intelligence* (New York; Basic Books)
17. Charles B Handy (1976) *Understanding organisations* (Harmandsworth: Penguin)
18. Paul Hawken, Amory Lovins and L Hunter Lovins (1999) *Natural Capitalism: Creating the next industrial revolution* (Boston: Little Brown)
19. John Houghton (2009) *Global Warming: The Complete Briefing* (Cambridge: Cambridge University Press)
20. Ivan Illich (1973), *Tools for Conviviality* (New York: Harper & Row)
21. Melvin Kranzberg and William H Davenport (1972) *Technology and Culture: An Anthology* (New York: Meridian)
22. Nick Lane (2009) *Life Ascending: The Ten great Inventions of Evolution* (New York: Norton)
23. Amory Lovins (1977) *Soft energy Paths: Towards a durable peace* (London: Penguin Books)
24. Donald A Norman (1999) *The invisible computer*: *Why good products can fail, the personal computer is so complex, and Information appliances are the solution* (Cambridge, Mass: MIT Press)
25. Donald A Norman (2004) *Emotional Design: Why we love (or hate) everyday things* (New York: Basic Books)
26. Victor Papanek (1974): *Design for the real world: Human Ecology and Social Change* (St Albans: Paladin)
27. Tom Philbin (2003) *The greatest inventions of all time: A ranking Past to Present* (New York: Citadel Press)
28. D S Pugh (Ed) (1975) *Organization Theory* (Harmandsworth: Penguin)
29. E F Schumacher (1999); *Small Is Beautiful: Economics As If People Mattered : 25 Years Later...With Commentaries*. Hartley & Marks Publishers
30. Herbert A Simon (2001): *The sciences of the artificial* (Cambridge, Mass: MIT Press)
31. J Scott Turner (2000) *The extended organism: The physiology of animal built structures* (Cambridge, Mass: Harvard University Press)
32. Steven Vogel 1998): *Cats' Paws and Catapults: Mechanical worlds of nature and people* (London: Penguin)
33. L D Vygotsky (1978) *Mind in Society: The development of higher psychological processes* (Cambridge, Mass: Harvard Univerity Press)
34. Mohamed Yunus (2001), *Banker to the poor* (Dhaka: The University Press Limited)