4 The technologies: identifying appropriate solutions for development needs

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- ICT4D initiatives need to be driven by the provision of appropriate technological solutions for the challenges faced by poor and marginalised people and communities, rather than by an interest purely in these physical technologies themselves.
- The choice of the optimal hardware and software solutions in any particular circumstance depends on a range of economic, social, political and ideological factors that need to be properly understood before any ICT4D initiatives are implemented.
- Convergence, miniaturisation and the shift from analogue to digital solutions have all created new opportunities that can be used creatively to empower poor people and marginalised communities.
- Those implementing technological solutions need to ensure that they are context specific and adapted to local needs and conditions.

Chapters 2 and 3 have explored the reasons why information and communication are central to 'development' processes. This chapter turns to an examination of the technologies that can be used to support these information and communication needs. Two key issues must be emphasised right at the beginning. First, it is essential to recognise that the actual technologies by themselves have little development impact. It is only when they are used effectively to deliver on the aspirations of poor people and marginalised communities that they may be able positively to influence their lives and livelihoods. Indeed, ICTs are often a financial drain on communities until there is sufficient wealth generated for them to provide enough profit for their continued use. Second, ICT4D initiatives are not sustainable or effective unless the technologies embedded within them deliver on the demands of users in appropriate ways. There is little point simply in introducing the technologies if users cannot see any economic, social or political benefit in paying for them. For this to happen, it is essential that potential users have a sound understanding of how they can use new ICTs beneficially. One of the most important challenges facing those implementing ICT4D initiatives is therefore to identify how best to respond to the needs of poor and marginalised communities once they have recognised this potential, and then to help them to develop innovative solutions that will enable them to achieve their aspirations.

This chapter provides a broad introduction to the diverse technologies that are referred to by those working in the field of ICT4D. The first section suggests that we need to be flexible in our definitions and approaches if we are to create effective technological solutions for the problems faced by the poor. The chapter then proposes a fourfold conceptualisation of ICTs, focusing on the technologies used in the *production*, *storage* and *sharing* of information and knowledge, as well as the *infrastructures* used to support them. Underlying the practical usage of these technologies, it is crucial to recognise that there are also important regulatory issues that determine the social, economic and political context within which they are introduced. The chapter ends by emphasising the importance of the debate between those advocating 'proprietary' and 'open' technological solutions for development agendas. Throughout, the aim is to highlight both the potential and the challenges associated with the use of specific technologies, so that those charged with implementing ICT4D programmes can have a realistic understanding of the contributions that each can make.

ICTs: a conceptual framework

There have been many approaches to the definition and classification of the technologies associated with information and communication. Frequently, the term ICTs is used primarily to refer to the use of computers and the internet. The Wikipedia Information Technology Portal thus refers to IT (or ICT) as the subject that deals with 'electronic computers and computer software to convert, store, protect, process, transmit and retrieve information' (http://en.wikipedia.org/wiki/Portal:Information_technology). In contrast, the online TechTarget definition places emphasis on the different types of technology themselves, claiming that ICT 'is an umbrella term that includes any communication device or application, encompassing: radio, television, cellular phones, computer and network hardware and software, satellite systems and so on, as well as the various services and applications associated with them, such as videoconferencing and distance learning' (http://searchsmb.techtarget.com/sDefinition/0,290660,sid44_gci928405,00.html). Weigel and Waldburger (2004, p. 19) similarly use the term to refer 'to technologies designed to access, process and transmit information. ICT encompass a full range of technologies – from traditional, widely used devices such as radios, telephones or TV, to more sophisticated tools like computers or the Internet' (see also von Braun and Torero, 2006). Hamelink (1997) has usefully sought to clarify this complexity, by distinguishing between capturing technologies (such as cameras and digital video recorders), storage technologies (such as CD-ROMs and film), processing technologies (such as application software), communication technologies (such as Local Area Networks) and display technologies (such as computer monitors or the screens of mobile phones).

A digital world

In the past it was possible to distinguish between separate ICTs such as telephones and radios, but since the late 1990s such distinctions have become increasingly blurred as a result of the widespread introduction of technologies that have enabled text, image and sound to be broken down into binary formats. This has allowed them all to be accessed through a range of new electronic devices. Digital processing, for example, has fundamentally transformed the practice of photography, enabling users to do away with film and instead access their photographs immediately. They can then 'post' them on the internet through sites such as http://www.flickr.com (see also social networking sites such as http://www.bebo.com or http://www.facebook.com) so that anyone in the world can see and access them almost instantaneously. This introduction of digital technologies has had two fundamentally important effects: first, it has enabled single devices, such as the new generation of portable media players and phones, to receive and display text, image and sound together; and second, it has permitted such multi-functional devices to become very much smaller and more mobile. The combination of miniaturisation with better use of power, enhanced compression of data, and digitalisation has led to a transformation in the potential of ICTs.

Traditionally, communication systems such as telephones, radio and TV functioned through the use of analogue technologies, with the term 'analogue' being used to refer to an analogy between cause and effect; as sound increases, for example, so too might the voltage of an analogous electrical system. Importantly, an analogue signal is one that continuously varies in both time and amplitude, and therefore all changes in the signal are meaningful. Using analogue systems, communication is enabled because small fluctuations in a signal can be conveyed by changes in the properties of the medium being used to transmit it. Transducers are used to convert energy of one type into energy of another that can then be transmitted. Thus, with the analogue recording of sound, a microphone is used to pick up variations in pressure caused by the sound, and these are then converted into changes in the current passing through it or the voltage across it. The main problem with analogue systems, though, is that they are subject to random variations and disturbance known as noise. This is particularly the case, for example, when multiple copies of a recording are made, since the noise leads to a reduction in the quality of the signal. Likewise, radio or TV signals can pick up interference from other such sources, and this noise then leads to a diminution in the quality of the sound.

In contrast, digital systems quantise signals into discrete blocks, and any slight variations are treated as the values nearest to them, thus minimising the effects of noise and distortion. Historically, there have been numerous systems of digital communication, perhaps best seen with the use of beacons that could convey messages over long distances by line-of-sight connections simply by being lit or unlit. Likewise, Morse code and Braille are both forms of digital communication, the former using dots, dashes and different lengths of gaps between letters, the latter using a six-bit code in the form of raised dot patterns. However, the term is now most frequently used to refer to digital electronic systems, in which information is encoded into binary digital format through the use of complex systems of switches. The underlying principle, though, remains the same, in that information is converted into a presence/absence format, and can be stored and accessed through a diversity of media.

Although digital electronic systems have increasingly come to dominate the market since their widespread introduction in the music industry in the 1980s, it remains important to recognise that both digital and analogue systems have their own particular strengths and weaknesses (Beards, 1996; Crecraft and Gergely, 2002). Their key differences are in the ways in which information is encoded, processed and represented. However, the easier design and smaller size of digital electronic circuits has made them much cheaper to produce, and they have therefore come to dominate the mass market in ICTs in the late 1990s.

A framework for conceptualising ICTs

In conceptualising ICTs in this rapidly changing and ever more dominantly digital world, it is helpful to think about these technologies as being associated with three main sets of interconnected processes: the capture of information, its storage, and the ways in which people access and share it. Underlying all these, there has to be a physical infrastructure in place that enables them to operate and be connected, and a regulatory mechanism to ensure that there are common standards in place for communication to be possible between devices (Figure 4.1). This chapter focuses primarily on the physical technologies and infrastructure, while the next includes a discussion of regulation in the context of policy formulation and the implementation of ICT4D partnership initiatives.

Means of information capture were traditionally discrete and quite large in size. Large typewriters and bulky cameras have now, for example, been replaced by ever more powerful slimline digital cameras and keyboards. The complexity of recording music and voices onto the analogue sound medium of gramophone records has likewise been dramatically transformed into the contemporary process of digital recording through which people can readily capture their own voices and music using small electronic devices. The size of devices for storage has likewise been transformed, largely through the introduction of digital circuits. Moore's Law, propounded by Gordon Moore, one of the co-founders of Intel, as long ago as 1965, asserted that the number of transistors per unit area on an integrated circuit was at that time doubling every two years. Today, the law has been reinterpreted to assert that data

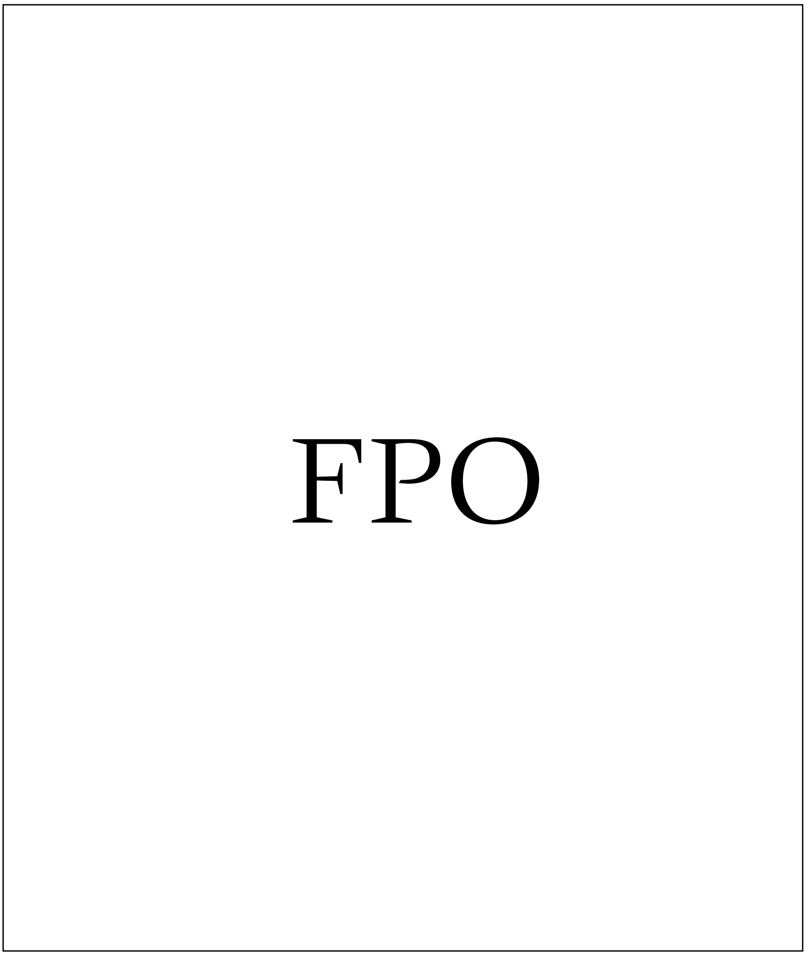

Figure 4.1 *Framework for conceptualising information and communication technologies*

density is now doubling approximately every 18 months. The technological advances that have underlain this mean that the size of storage devices has been reduced dramatically, while it has been possible to increase their capacity at the same time. As Intel's website asserts: 'Moore's Law also means decreasing costs. As silicon-based components and platform ingredients gain in performance, they become exponentially cheaper to produce, and therefore more plentiful, more powerful, and more seamlessly integrated into our daily lives' (http://www.intel.com/technology/mooreslaw/index.htm). In 1971, Intel's first processor, the 4004, had 2300 transistors in it; in 2006, Intel's Core 2 Duo Processors had more than 291 million transistors. The 4004's circuit line width was 10 microns, whereas the latest generation microprocessors have widths of 0.065 microns, fifteen hundred times smaller than the diameter of human hair (http://www.intel.com/museum/archives/4004facts.htm).

Figure 4.1 emphasises the diversity of options that people can use to communicate and to manage information. This chapter aims to give a balanced overview of some of the most important of these, focusing particularly on the ways in which poor and marginalised communities can use them to gain information and to communicate more effectively. It begins by examining the increasingly sophisticated ways in which information is captured and stored, concentrating on three particular issues: the use of printed material for libraries; the role of multimedia material; and the increasing significance of the internet. None of these technologies would be of any use unless there were appropriate physical infrastructures available to enable them to function effectively. The third main section of this chapter therefore focuses explicitly on four key aspects of infrastructure provision: cables and wires; satellites; wireless networks; and appropriate energy solutions. This is followed by a section that explores the benefits and challenges associated with the use of specific user interfaces, both for accessing information and for communicating more generally, concentrating on telephones, computers, new handheld devices, and the role of radio, television and film. In addressing these particular technologies, however, it must emphasised once again that they are already all closely interconnected and the boundaries between them will become ever more blurred in the future. In particular, the distinction between users and suppliers of information is one that is rapidly changing. The internet has enabled a much more fluid world of communication in which people can share information with each other, instead of having to rely primarily on the 'supply' of information by privileged organisations such as broadcasters and publishers, be they public service organisations or private companies.

Individual and communal technologies

Different types of technology, both hardware and software, have varying potential uses in ICT4D initiatives. Figure 4.2 illustrates three dimensions of these technologies: their costs to end users, their ease of access, and the extent to which they are communal or individual (see also Weigel and Waldburger, 2004). In general, to the right of the figure there are low cost, easy to use and communal solutions such as radio, and to the left there are high cost, complex and individual solutions such as personal computers linked to the internet. While these categories are by no means mutually exclusive, it is often the case that easier to use technologies are indeed cheaper, and have wider communal use than expensive and complex technologies. This is typified, for example, by the success of Grameenphone's Village Phone Program (http://www.grameenphone.com) started in 1997 in Bangladesh, which was designed to provide universal access to telecommunication services in remote rural areas through a network of some 200,000 village phone operators, most of whom are women (for communal

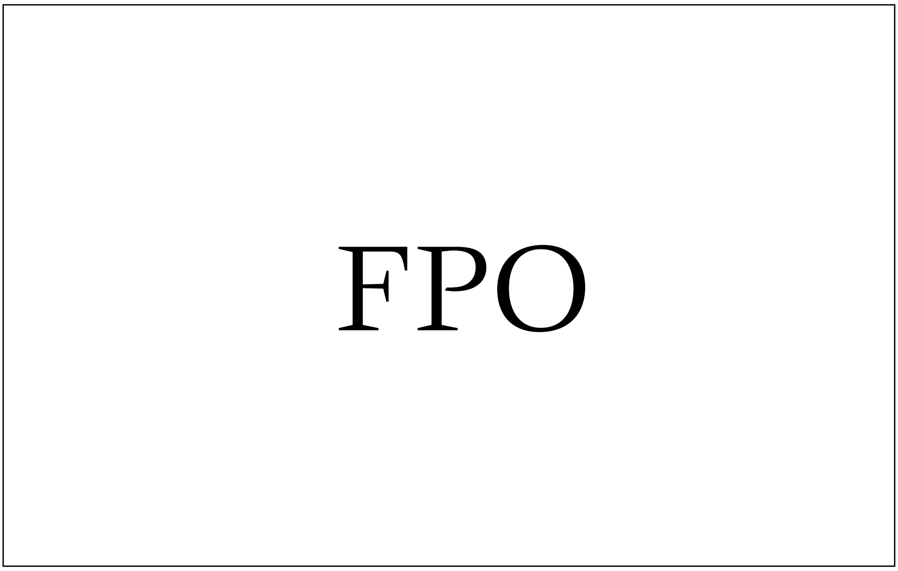

Figure 4.2 *Costs to end user and ease of access of ICTs (derived in part from Weigel and Waldburger, 2004)*

aspects of mobile phones, see also Geser, 2004; Souter *et al.*, 2005). While expanding the market for high-cost individualised technological solutions may contribute to the economic growth seen by many as being central to development processes, alternative communal solutions may prove to be much more sustainable and relevant to the needs of poorer communities. These issues are explored further in the section 'Individuals and communities: debates over software and content', which focuses particularly on the different software solutions available and the potential of open learning resources.

The capture and storage of information

The introduction of small and relatively cheap information capture and storage devices has transformed the world in which we live. Not only is this a remarkable technical transformation, but importantly it also offers a rare opportunity to change the traditional balances of power associated with the provision of access to information. New ICTs have provided an increased chance for the democratisation of knowledge in ways that have not yet fully been grasped. This section explores these issues in three main arenas: libraries, multimedia technologies, and the internet.

The changing place of libraries

Historically, library buildings have been the main place where information has been stored and made available for people to read. Indeed, as Klugkist

(2001, p. 197) has commented: 'until the 1980s and 90s, libraries virtually had a monopoly on the provision of information to students, teachers and researchers'. Libraries served a public good in that they were usually free to use and they frequently offered a range of additional services including the provision of information about the local community as well as other learning opportunities. Libraries, in essence, served the needs of those individuals unable to afford to purchase their own books and information.

During the last twenty years of the 20th century, two fundamental changes took place that transformed libraries: first, the dramatic increase in the number of books, journals and other printed media being published has meant that it is impossible physically for most libraries to store it; second, the availability of digital technologies has enabled much of this information to be accessed in entirely new ways. The provision, for example, of both hard copy and digital versions of publications is completely transforming the world of publishing and academic research. While there are undoubted cost savings and presumed environmental benefits in the shift from hard-copy books and journals to digital publication, there nevertheless still remain problems in accessing such information in a sufficiently flexible and user-friendly manner. Thus, although digital book downloads are readily available, most people still prefer to read 'real' rather than 'virtual' books. This is particularly the case with elderly people, whose eyesight might be failing.

In exploring what libraries will be like in the future, Klugkist (2001, p. 197) has usefully suggested that they will be a gateway to information, an expertise centre, a physical entity, and a collection centre for printed material. According to such arguments (see also Saunders, 1999), digital information will not replace libraries as places where information is accessed, but rather the means of accessing this information within libraries will change. As Dendrinos (2005, unpaginated) has commented: 'The library as a building has been transformed to the library as an environment of electronic services established on a computer server or a network of cooperating servers'.

The emergence of digital libraries has required the development of new systems of cataloguing and searching publications so that information about them can readily be searched and made accessible to potential users (Lesk, 2005). In 1994, the USA established a Digital Libraries Initiative (http://www.dli2.nsf.gov/dlione), funded by the National Science Foundation, with a remit to 'collect, store, and organize information in digital forms, and make it available for searching, retrieval, and processing via communication networks – all in user-friendly ways'. Likewise, in the latter part of the 1990s, the New Zealand Digital Library Project began at the University of Waikato, and with the collaboration of UNESCO and the Human Info NGO from 2000, this led to the production of the Greenstone multilingual suite of open-source software for building and distributing digital library collections either on the internet or on CD-ROM (http://www.greenstone.org;

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The Greenstone Digital Library Software

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The New Zealand Digital Library Project (Witten and Bainbridge, 2003, 2007) was established in 1995 and grew out of research on text compression (Bell *et al*., 1990) and, later, index compression (Bell *et al*., 1994; Witten *et al*., 1994). Initially, it consisted of a collection of 50,000 computer science technical reports downloaded from the internet (Witten *et al*., 1995). We were assisted by one-off equipment funding from the New Zealand Lotteries Board and operating funding from the New Zealand Foundation for Research, Science and Technology (1996–1998 and 2002–present).

In 1997 we began to work with Human Info NGO to help them produce fully searchable CD-ROM collections of humanitarian information. The first publicly available CD-ROM, the Humanity Development Library 1.3, was issued in April 1998. A French collection, UNESCO's Sahel point Doc, was issued a year later. The first multilingual collection appeared six months later: the Spanish/English Biblioteca Virtual de Desastres/Virtual Disaster Collection. Since then about 40 CD-ROM collections have appeared. At this point we realised that we did not aspire to be a digital library site ourselves, but rather to develop software that others could use for their own digital libraries.

Towards the end of 1997 we adopted the term Greenstone: we decided that 'New Zealand Digital Library Software' was not only clumsy but could impede international acceptance and so sought a new name. 'Greenstone' turned out to be an inspired choice: snappy, memorable, and un-nationalistic but with strong national connotations within New Zealand. A form of nephrite jade, greenstone is a hallowed substance for Māori, valued more highly than gold. Early releases were posted on our website greenstone.org (which was registered on 13 August 1998), but in November 2000 we moved to the SourceForge site for distribution.

We became acquainted with UNESCO through Human Info's long-term relationship with them. Although they supported Human Info's goal of producing humanitarian CD-ROMs and distributing them in developing countries, UNESCO was really interested in sustainable development, that is, empowering people in those countries to produce and distribute their own digital library collections. We began to aspire to put the power to build collections into the hands of non-technical people (Witten *et al*., 2001; Bainbridge *et al*., 2003). From the outset, UNESCO's goal was to distribute the entire Greenstone software (not just individual collections plus the run-time system, as in Human Info's products) on CD-ROM, so that it could be used by people in developing countries without ready access to the internet. These CD-ROMs contained all the auxiliary software needed to run Greenstone as well, which is not included in the internet distributions because it can be obtained from other sources. When we and others started to give workshops, tutorials and courses on Greenstone, we adopted a policy of putting all instructional material — PowerPoint slides, exercises, sample files for projects — on a workshop CD-ROM, and began to include this auxiliary material on the UNESCO distributions.

Good documentation was (rightly!) seen by UNESCO as crucial. They were keen on making the Greenstone technology available in Spanish, French and Russian. The cumbersome process of maintaining up-to-date translations in the face of continual evolution of the software led us to devise a scheme for maintaining all language fragments in a version control system so that the system could tell what needed updating. This resulted in the Greenstone Translator's Interface, a web-based interface where officially registered translators can examine the status of the language interface for which they are responsible and update it (Bainbridge *et al.*, 2003).

With UNESCO's encouragement, we have worked to enable developing countries to take advantage of digital library technology by running hands-on workshops. Recognising that devolution is essential for sustainability, we are now attempting to distribute this effort by establishing regional Greenstone Support Groups. One for South Asia was launched in 2006 and another for Southern Africa in 2007.

see also Bainbridge *et al.*, no date, and http://www.nzdl.org). This has provided a valuable tool for development-related work, enabling the creation of digital libraries such as the Bibliothèque pour le développement durable library in 1999 (http://nzdl.sadl.uleth.ca/cgi-bin/library?a = p&p = about&c = tulane) as well as the UNAIDS library (http://nzdl.sadl.uleth.ca/cgi-bin/library?a = p&p = about&c = unaids) (see the case study 'The Greenstone Digital Library Software' on p. 000). Similar initiatives include the EU's Digital Libraries Initiative and eContent*plus* Programme (http://ec.europa.eu/information_society/activities/digital_libraries/index_en.htm, http://ec.europa.eu/information_society/activities/econtentplus/index_en.htm). Moreover, Google Book Search now provides a facility whereby users can read and search an array of books online, and the Google Books Library Project enables people to gain information about books not yet available online (http://books.google.com/googlebooks/library.html).

Accessing many of these new bibliographic resources nevertheless remains a challenge for the poor. While university libraries in the world's rich countries subscribe to vast collections of online journals, the costs of such access remain prohibitively high for institutions in many of the poorer countries of the world. Likewise, having sufficient bandwidth as well as appropriate terminals from which to access these materials gives rise to serious challenges, particularly for marginalised communities. Much work remains to be done in ensuring that appropriate content is developed and made available as extensively as possible to users who cannot afford it.

Multimedia materials

As Chapter 3 highlighted, the use of film and audio in development practice has a long tradition. However, recent advances in digital technologies have transformed the production and storage opportunities associated with such media. Whereas in the past it was complex, costly and bulky to make films or audio-tapes, the use of small digital recorders has brought this opportunity to many people in a relatively easy-to-use and low-cost context. Moreover, the explosion of interest in sharing still and video images among friends and communities through the internet, using sites such as http://www.flickr.com, http://www.youtube.com or http://www.myspace.com, reflects the scale of the social demand for such practices. YouTube, which was only launched in February 2005, was bought by Google for US$ 1.65 billion in October 2006, at which point some 100 million videos were being viewed each day. Such potential has not yet, though, been widely used for development purposes, with a search on YouTube on 22 December 2006 listing only 214 videos for the words 'Africa' and 'development', including a seven-minute video entitled *Achieving the Millennium Development Goals* (http://www.youtube.com/watch?v = ReRx12QUv54, accessed 22 December 2006) which had at that date been viewed by 1,400 people. By 7 January 2008, there had been a considerable increase in interest in development agendas, with 948 videos being revealed in a search for 'Africa' and 'development', and 9,670 people having viewed the MDG video. These figures nevertheless remain paltry beside the 60,000 videos posted with reference to George Bush or 81,4000 on Britney Spears; there were also 28 videos on ICT4D.

The production of multimedia resources has enormous potential for development practice. Paradoxically, though, much of this potential has yet to be realised in full. In part this reflects the expense of developing and editing really high quality multimedia resources. However, it also reflects a general focus on the use of text-based resources in most learning and teaching environments. Among the most important advantages that film, video and audio can bring to information sharing and knowledge creation in the development context are: their ability to incorporate several senses in the learning experience; an opportunity to provide information that cannot easily be shown in other ways; the use of a story line that can link issues to emotions; their ability to be shown on widely available television sets or even projected onto a sheet hung between trees; and their use as a catalyst for discussion.

Traditional film and video-tape production and storage had four main drawbacks: cameras, processing equipment and projection facilities tended to be very bulky and complex to use; the materials and equipment were relatively expensive; the video-tapes or films did not last long in harsh environments; and they were not conducive to interactivity because the tapes ran in sequence from beginning to end, and were therefore not easy to search for particular scenes or sequences that participants might want to return to for discussion. Many of these issues have now been overcome through the introduction of digital technologies. Cameras today are much cheaper and smaller; there are no expensive film processing costs; relatively little training is required for people to learn how to edit digital video on a computer; CDs or DVDs are cheap and robust in harsh environments; and content is readily searchable and playable for group discussion purposes (see GTZ and inWent, 2003). Good examples of such material include the 20-minute video *Understanding Livelihoods: complexity, choices and policies in Southern India* produced by Catcher Media (no date) for DFID (High *et al.*, 2001; see also http://www.livelihoods.org/info/tools/UL_video.html), and the film *A Mother's Story* made by the Mediae Trust in Kenya in 2000 for the National Malaria Control Programme, which was shown at the annual Roll Back Malaria Global Partners Meeting in Geneva that year, was subsequently incorporated into a CD by Imfundo's partners (http://imfundo.digitalbrain.com), and was later made accessible online (http://www.gg.rhul.ac.uk/ict4d/Malaria.html).

It is important to distinguish between two different types of use of film, video and audio resources: those developed and made by external agents for a particular development learning or dissemination purpose; and those

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The internet of things

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The internet began in the 1960s as a link between a few university computer centres; in the 1970s and 1980s the users were counted in thousands, and the predominant applications were e-mail and file transfer; in the 1990s, web browsing became dominant and users were counted in millions. Today, in the 2000s, we are at the start of a new era, in which computer devices will be embedded in everyday objects, invisibly at work in the environment around us. Communication networks will connect these devices together to facilitate anywhere, anytime, always-on communications. The users of the internet will be counted in billions, with humans becoming a minority.

Key technological enablers for the success of this so-called *internet of things* have been identified as radio-frequency identification (RFID) and wireless sensor networks. RFID is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. A RFID tag is an object that can be attached to or incorporated into a product, animal or person for the purpose of identification using radio waves. In order to connect everyday objects and devices to databases and networks, a system of item identification is necessary. Anything, from a house key to a human being, has the potential to become a node of the internet.

Wireless sensor networks are one of the key building blocks of the internet of things. A sensor node or 'mote' is an electronic device which detects, senses and measures physical phenomena such as heat, motion or light, and responds in a specific way. Being wireless devices, they can easily be deployed even in hostile environments. Sensors collect data from the environment, generating information about their context that can be used to adapt the computing system. The sensors are portable, reliable and low-cost, and can be battery operated. RFID and sensors can create an environment in which the status of objects can readily be determined, monitored and communicated.

These emerging technologies have the potential to offer economic, social and environmental benefits, and the developing world merits special attention. RFID, for example, has been used to track and monitor containers of frozen beef and chicken exported from Namibia to the UK. For Namibia, beef is one of the main items of export to the EU, and tagging containers with RFID sensors ensures the quality of meat. In India, the emerging apparel industry has likewise started to look into RFID to improve its supply-chain efficiency and to comply with international standards.

Smart sensors have much to offer to developing countries. The deployment of a wireless sensor network can enable the measurement of environmental data and its forwarding to the internet, thus allowing researchers to analyse it at a distance. The development of water quality control technologies is essential: in many developing countries, both surface and ground water contain biological and chemical contaminants but the appropriate technology for measuring the type and degree of contaminants in water is lacking. The advantage of wireless sensor networks (WSN) is that they can determine the quality of water with a dense spatio-temporal resolution. A WSN to monitor water quality has been deployed in Bangladesh, where people in the Ganges Delta drink ground water that is contaminated with arsenic. A manual arsenic sensor, combined with the data collected from the sensor network, has been used to get a better understanding of the groundwater chemistry at shallow depths. A WSN has similarly been deployed in Ethiopia to monitor antiretroviral drug therapies for AIDS. The system is expected to replace paper-based handwritten data collection systems currently used to track the progress of the disease. The sensors used in the project were initially developed for use in monitoring vital signs of astronauts in space. These will now help collect information, transfer the data via wireless systems to a base station connected to the internet and facilitate tracking of disease outbreaks.

used in a participatory way as part of a self or communal learning process. Both have value in development practice. The former category includes most materials made as contributions to the enhancement of development practices as mentioned above. As Bohmann (2003, unpaginated) has commented, 'These media are usually used in group work to arouse interest in a topic, to transfer certain information, and as a didactic instrument at the micro level'. They can also be used to raise general awareness of development issues among people in richer countries and more privileged societies. However, an alternative and important use of video, and sometimes also audio, is in participatory methods (see White, 2003), and notably in the regular monitoring of performance (Lunch, 2007). The use of video by teachers to monitor their own teaching performance, or by doctors in the way in which they respond to patients, can thus be extremely useful in enhancing the delivery of education and health provision.

The power of the internet and the World Wide Web

It is important to distinguish between two often confused terms: the internet and the World Wide Web (or Web). The internet is essentially a connection of interconnected computers, or a network of networks (Abbate, 1999), whereas the World Wide Web (or Web) is the body of resources accessed by hyperlinks, commonly called uniform resource locators (URLS), that is accessed over the internet. As the number of computers increases, so too does the power of the internet, but only if these computers are effectively and efficiently connected. Hence the amount of computer memory and the channel capacity between computers, often referred to as the bandwidth, are absolutely essential components of the internet. The modern Web provides the world's greatest source of information storage, combining the memory contained in all of the computers of the internet. Moreover, because anyone with a computer terminal and the appropriate software can now upload material, it has transformed traditional processes of information capture, sharing and retrieval (see the case study 'The internet of things' on p. 000).

For the internet to function at all, some computer systems, known as servers, need to run permanently, so as to provide the required services to other computers within a given network that wish to access them. These servers include mail servers that handle e-mails, application servers that run applications, and file servers that store files and databases. The internet then works by enabling data to be transmitted in 'packets' through a range of mechanisms, such as through wires, fibre-optic cables or by radio waves (see 'The physical infrastructure', below). So that users can know what data they want to access, a system of rules for addresses has been constructed that enables computers to communicate, and this is known as the Internet Protocol or IP; each computer is allocated a unique IP address that enables it to communicate with any other computer on a network. The dominant IP version in use for the internet today is IPv4, which was released in 1981 (ftp://ftp.rfc-editor.org/in-notes/rfc791.txt) and uses 32-bit binary addresses (usually written as four groups of decimal numbers each representing eight bits as in 213.207.6.42) enabling it to have some 4 billion potential addresses. With the rapidly increasing number of computers, it has been necessary to expand this, and its successor is likely to be IPv6 which uses 128-bit addresses and therefore has the potential for 3.4×10^{38} addresses (Loshin, 1999; Miller, 2004). In enabling computers to access data from other computers, it is crucial for data packets to be routed efficiently, and hence much attention has been paid to the design and development of 'routers' that enable path selection to be optimised.

Much of the early development of the internet (Leiner *et al.*, 2003) and its associated protocols and technologies was undertaken within the Defense Advanced Research Projects Agency (DARPA) of the US Department of Defense, evolving from the ARPANET project in the late 1960s. It is therefore no coincidence that most of the control of the internet remains in the hands of US institutions. The system of assigning IP addresses has been particularly controversial. It was embedded in the early work of DARPA, and by the late 1980s the US government had established an Internet Assigned Numbers Authority (IANA, http://www.iana.org) to fulfil this role. Then in 1998 the Internet Corporation for Assigned Names and Numbers (ICANN, http://www.icann.org) was established as a non-profit corporation based in California to manage these and other internet-related functions, particularly the assignment of domain names and IP addresses. This dominance of the USA in internet governance has become a topic of considerable debate, and was one of the key issues discussed during the Tunis phase of the World Summit on the Information Society in 2005 (see pp. 000–00 Huston, 2005).

The amount of traffic using the internet has increased dramatically since its origins in the late 1960s (see *Amateur Computerist*, 2007). By the start of 2008, it was estimated that there were more than 1.26 billion users, representing more than a doubling in use since 2000 (Internet World Stats, http://www.internetworldstats.com/stats.htm, accessed 7 January 2008). However, as Table 4.1 emphasises, such usage is highly variable across the world. Asia, for example, has the most internet users, but this largely reflects its huge population, of which only 13.7% were actually internet users at the end of 2007. In contrast, North America has the highest percentage of internet users among its population (71.1%), but the lowest usage growth rate (120.2%). The fundamental point to note about these figures is that internet access is still low in Africa, Asia, Latin America, the Caribbean and the Middle East, and even within these regions it is primarily the rich who benefit most from its potential. While many innovative ICT4D projects have been developed, and the pace of change is accelerating rapidly in these regions, the fundamental conclusion that must be drawn is that at present other technologies have much greater potential to deliver the information and communication needs of poor people. If we are truly to aspire to digital equality, with poor people indeed being empowered through the internet, we still have a very long way to go. Indeed, Table 4.1 is a reminder that,

Table 4.1 *Internet usage statistics, December 2007*

	Internet users (millions)	Internet users as % of population	Internet usage growth 2000 – 2007	Usage as % of world use 2007
Africa	44.3	4.7%	882.7%	3.4%
Asia	510.5	13.7%	346.6%	38.7%
Australia/ Oceania	19.2	57.1%	151.6%	1.5%
Europe	348.1	43.4%	231.2%	26.4%
Latin America/ Caribbean	126.2	22.2%	598.5%	9.6%
Middle East	33.5	17.4%	920.2%	2.5%
North America	238.0	71.1%	120.2%	18.0%
World total	1,319	20.0%	265.6%	100%

Source: Internet World Stats (http://www.internetworldstats.com, accessed 19 February 2008)

however much work has been done over the last decade in seeking to implement beneficial internet-based learning and health initiatives, these are only scratching the surface of poverty and marginalisation in the poorest regions of the world.

It is not only at a global level that there are striking differences in internet usage. As Figure 2.2 illustrates, even within the poorest regions of the world, there are vast differences. While north African countries such as Tunisia (15.7%) and Egypt (7.5%) generally have more than 5% of their populations being internet users, this figure falls to as low as 0.03% in Liberia, and most sub-Saharan countries have less than 1% of their populations using the internet in 2007 (http://www.interworldstats.com). Moreover, even where there is access, the quality of access may be extremely poor, reflected in slow download and upload times, unreliable connectivity and high cost. Only when the internet can be reliably available at a price that poor people can afford will it become a powerful tool for their empowerment.

The physical infrastructure

All communication systems require a physical infrastructure to be in place to provide energy and to generate and receive signals. Without such infrastructure, none of the complex systems of computers, radios or mobile phones that exist today would be able to function. The provision of physical infrastructure, though, is often one of the least considered aspects of ICT4D programmes. On more than one occasion, ambitious programmes have been developed to introduce computers into schools, only for it to be realised subsequently that the absence of electricity has meant that only a few such schools would actually be able to benefit. Indeed, much of the inequality in the distribution of the benefits of ICTs can be attributed to a spatially differentiated supply of basic infrastructure. One of the reasons why China's initiatives to introduce educational television into schools have, for example, been so successful, is that they were preceded by a substantial programme of rural electrification (Pan *et al.*, 2006) with the launching of appropriate satellites then enabling television signals to be relayed throughout the country. In contrast, the lack of a basic and reliable electricity supply across much of Africa today remains one of the greatest handicaps to the continent's development.

In exploring the most relevant infrastructural needs, it is useful to distinguish between two main different types of system, those that use wires or cables and those that do not. Within the latter group it is common to differentiate between terrestrial wireless technologies and the use of satellites. As well as the actual media used, this section of the chapter also pays explicit attention to the energy needs associated with ICTs and questions surrounding their sustainability. It is important to recognise that the choice of infrastructure depends on many factors, including the physical environment in which one is seeking to provide a solution, the distances involved, the security that is required, as well as the need for flexibility in response to future changes in capacity, and the regulatory environment within which the technology is to be deployed (McQuerry, 2004).

Cables and wires

Until recently, most telecommunication systems used wires as the medium to connect transmitters and receivers using analogue systems. Voice was converted by a microphone to electrical signals that were transmitted down a wire to a speaker that would then convert the waves back to sound. The earliest telephone lines were simply wires made of iron or steel. These rapidly corroded, and it was not until the introduction of hardened copper wires in the late 19th century that a successful basis for effective telephony was established. Bell then introduced a two-wire circuit to replace the single grounded wire system in 1881, and in essence this principle remained the basis of most telephone systems throughout the 20th century, although numerous subsequent innovations enabled increasing capacity to be carried. The original telephones were connected in pairs, but as demand grew individual telephones were connected to exchanges, so that they could then use shared lines between exchanges to connect to any number of other telephones. Initially human operators would connect people to those with whom they wanted to speak. However, advances in telecommunications technology by the mid-1960s enabled electrical switches controlled by pulses sent by the caller's phone to connect the user's line with the number required.

By the late 20th century, the introduction of digital systems transformed telephony, permitting digital signal processing over existing twisted-pair telephone wires. This enabled people with modems to connect these to their normal telephone lines to carry digital signals as well as voice. Digital subscriber lines (DSL), using frequencies above those needed in voice telephone conversations, in conjunction with standards and protocols known as integrated services digital network (ISDN) systems were then introduced to enable complex voice, text and video over normal copper telephone wires. In particular, asymmetric digital subscriber line (ADSL) technology, with flows of data greater in one direction than the other, have now enabled copper wires to retain their place in the market.

As with all technologies, copper wires and cables have both advantages and disadvantages. With copper prices being relatively cheap, and with new algorithms and hardware enabling ever-faster transfer of voice and data, it is likely that traditional telephone cables will continue to be used in this way for some time to come. However, with the dramatic expansion in mobile telephony and in areas where existing cables have not already been laid, it may well be that alternative solutions will become much more popular. This is especially so given the ease with which copper cables can be tapped, and the extent to which they are stolen in many poor countries (Mbarika, 2002).

Fibre-optic technology has recently provided a fundamental challenge to telecommunications systems based on copper wires. It has the particular advantages of being able to carry very much more traffic and of being much less able to tap into than traditional copper cables. Fibre optics, based on the passing of light through a glass or plastic fibre, were first used in the communications industry in the 1970s, and the field has expanded very rapidly since (Hecht, 2002). The first transatlantic cable using fibre optics went into operation in 1988, and during the 1990s the introduction of photonic crystal fibre, which uses diffraction from a periodic structure rather than total internal reflection to transmit light, led to a considerable increase in capacity. Fibre optics have four key advantages over copper cable: they have much less loss on transmission, and therefore permit long distances to be covered without repeaters or amplifiers; they have very much greater data-carrying capacity or bandwidth; when laid alongside each other, they do not suffer from the 'cross-talk' associated with copper cabling; and they are also very much lighter. Although the costs of production and deployment of fibre-optical cable are higher than for traditional copper cabling, these advantages mean that many of the richer countries of the world are now providing broadband access with previously undreamt of capacity through the use of fibre optics (see for example http://billaut.typepad.com). As yet, though, only a very small percentage of the total fibre-optical capacity in the world is used, and it is likely to be several more years before it comes to replace traditional copper cabling. If sufficient funding can be made available, though, there is a strong case for poorer countries of the world to install fibre-optic cables from the very beginning in areas that are not yet served, so that they will have the bandwidth capacity for the delivery of services in the future as they become available.

An alternative wired solution to the provision of digital connectivity is through the use of electric power lines, known as power line communication

(PLC) (see for example International Powerline Communications Forum, http://www.ipcf.org and http://www.powerlinecommunications.net; Dostert, 2001). In essence, this can provide communication links wherever electricity flows, by impressing a modulated carrier signal onto the wiring system. This can apply equally through the wiring system of a house, or across a national electricity transmission network. Such systems eliminate the need for separate digital wiring, and have the distinct advantage that they can provide broadband connectivity wherever there are power lines (BPL – broadband over power lines). However, the lack of standardisation in the provision of electricity services, the noisy environment of power lines, and existing regulatory frameworks have all limited the expansion of BPL to date. In the future, particularly in rural areas, there is nevertheless potential for power lines to provide a service backbone with wireless systems then providing wider connectivity from transmitters along the route of a power line.

Wireless solutions

Wireless technology replaces the need for the medium of cables and wires by using parts of the electromagnetic spectrum to transmit signals. An alternating current is applied to an antenna to produce the waves, and these can then be picked up by a receiver which converts them back into sound, pictures or data. Wireless technologies are often divided into three types: short-range communication between devices; broadcast distribution; and last-mile solutions (Panos, 2006). Wireless technologies use 'radio' frequencies (those electromagnetic waves that lie in the range of 3 Hz to 300 GHz). These can be subdivided into specific groups according to their frequency and wavelength. As frequency increases, wavelength decreases, and these properties mean that different parts of the spectrum are suitable for particular purposes. Thus very low to extremely low frequencies between 3 Hz and 30 KHz, with wavelengths of 100,000 km to 10 km, often known as sonar (sound navigation and ranging), are used for communicating with submarines and geophysics. Radio and television broadcasting generally uses the range from 30 kHz to 300 MHz, and microwave ovens, mobile phones, wireless local area networks (LANs) and Bluetooth use ultra high frequencies of 300–3,000 MHz, with wavelengths generally between 1 m and 100 mm. Three general principles underlie the use of these different spectra:

- the longer the wavelength, the further it goes;
- the longer the wavelength, the better it travels through and around things;
- the shorter the wavelength, the more data it can transport.

(Alchele *et al.*, 2006, p. 16)

Thus radio broadcasting uses longer wavelengths than television since it needs to send less data, and digital broadband – which needs to transport very large amounts of data – uses much shorter wavelengths.

At present, there are two main wireless technologies of interest for data transfer: Wi-Fi (first standards in 1997) and WiMAX (since 2001). Until recently, there were three main Wi-Fi (Wireless Fidelity) standards in use: 802.11 b and g for frequencies between 2.412 and 2.484 GHz, and 802.11 a operating between 5.170 and 5.805 GHz (Gast, 2005). These were largely replaced in 2007 by 802.11-2007. For WiMAX (Worldwide Interoperability for Microwave Access), the original standard was 802.16 for the 10 to 66 GHz range, and this was updated in 2004 (802.16-2004, also known as 802.16d) to add specifications for the 2 to 11 GHz range, being further amended in 2005 to the 802.16e-2005 standard (Andrews *et al.*, 2005). There are important differences between the Wi-Fi and WiMAX standards. In essence, signals from all those wishing to use Wi-Fi must pass through a wireless access point on a random access basis, whereas WiMax uses a scheduling algorithm which not only makes it more stable but can also ensure that appropriate bandwidth is allocated to control the quality of service delivered. Generally speaking, Wi-Fi is more appropriate for small networks requiring shorter ranges of several hundred metres, as within a single organisation. In contrast, WiMAX provides solutions over several kilometres typically with a point-to-point connection between an internet service provider (ISP) and an end user (http://www.wimaxforum.org/technology).

All wireless technologies need some kind of transmitter, or antenna, as well as a receiver. One of the key differences between radio and television broadcasting on the one hand and wireless digital technologies on the other is that because of their longer wavelengths the former can pass around obstacles whereas the latter generally cannot. This is why, when designing wireless networks for high bandwidth data transmission, it has until recently been essential to have line-of-sight visibility between the antenna and the receiver. The longer wavelengths of the WiMAX standard are now making this less of a restriction. In designing wireless internet networks, three different configurations are often identified: point-to-point, where a single remote site is linked to a central hub; point-to-multipoint, where a central hub links to a number of remotes; and multipoint-to-multipoint, where all of the points can interconnect with each other. Each of these alternatives can have applications in different circumstances depending on the particular needs of the user, and the constraints placed on them. Likewise, it is important to emphasise that the initial internet connection to the central antenna can be provided in a variety of ways, either through cable or via satellite.

Wireless technologies have immense potential in poor countries and communities, especially where good line-of-sight visibility is possible (for a wide discussion see Castells *et al.*, 2007). In flat areas, a mast can be erected, and in mountainous parts of the world point-to-point connections can be provided by locating antennae on the highest ground. Where there are fears over theft, it is generally also far easier to protect antennae than it is to keep an eye on lengths of cabling over long distances. There are, though, different security concerns with respect to wireless, because the networks are based on a shared medium and their traffic is therefore visible to all users. Where data security is of importance, it is thus essential to use encrypted systems and to maintain effective authentification procedures. Another critical factor that needs to be considered in the use of wireless is the regulatory environment in place, not only within a country but also globally. Without a clearly defined set of rules to control the use of different wavelengths, only those with the most powerful transmitters, or in closest proximity to an antenna, would be able to send or hear a signal. Hence, complex systems of regulation and standards have been put in place to enable these issues to be managed effectively (Bekkers and Smits, 1999; see also Chapter 5).

Satellites

Satellites are a central part of modern wireless technology. As well as providing means for disseminating radio and television broadcasts widely across the globe, they have increasingly also been used for telephony and multimedia data services. Satellites provide a very important mechanism for enabling digital connectivity in parts of the world poorly served by traditional wired infrastructures, but the initial cost of launching them means that the provision of these services by satellite is an expensive option. Vanbuel (2003, p. 7) has highlighted five key advantages that satellites can provide:

- 'Reception is possible with small antennae.'
- It is possible to have instant connection almost anywhere within the footprint of a satellite, without the need for any cabling or other terrestrial infrastructure.
- The equipment that consumers need to purchase is relatively low-cost
- 'Internet connectivity can be combined with traditional broadcasting technologies such as digital TV and Radio, enabling content providers to select the most appropriate delivery means according to the type of content.'
- The use of satellites for one-way multimedia push services such as data broadcasting is very efficient, because they do not require a modem and internet connection for the return link.

Satellites reflect wireless signals from a transmitter on the ground, the uplink, to receivers somewhere else in the world, the downlink. They do this through transponders, which receive the signals from the transmitting Earth station, translate them, and then relay them to an antenna that transmits them back to earth. Satellites in general have several transponders on board, and they can therefore deliver various communication channels together at the same time. Broadly speaking, there are two main kinds of satellite: geosynchronous ones that travel 36,000 km above the Earth, making one orbit every 24 hours, thus appearing stationary above a particular part of the

Earth's surface; and those that travel much faster at less distance from the Earth in either medium or low orbits. The advantage for users of geostationary satellites is that Earth stations can be fixed in their orientation to pick up their signals, but these satellites require more power to transmit the signal than do low or medium orbiting satellites that are nearer the Earth's surface.

One particular application of satellite technology, very small aperture terminal (VSAT) systems, has become particularly prevalent in recent years to provide communication services for a range of uses, from corporate banks to rural telecommunications. VSAT solutions, using dish antennae less than 3 m in diameter, 'provide very efficient point-to-multipoint communication, are easy to install, and can be expanded at low extra cost' (Vanbuel, 2003, p. 31). VSAT is very flexible, and can provide any digital services, including telephony, broadband internet and video-conferencing. For this reason, they have become a popular development solution, exemplified in contexts as diverse as the World Bank's Global Development Learning Network (GDLN) (http://www.gdln.org), which now has some 120 learning centres in nearly 80 countries, and the contracts won by Gilat (http://www.gilat.com) for providing telecommunication services in India and Africa. Problems in implementing the latter have, however, highlighted the costs and complications of using VSAT in rural areas of poor countries.

The type of equipment needed on the ground to receive satellite signals varies with the type of intended usage. Key considerations for users of satellite services are the cost of the ground equipment and the amount paid for the services provided. Cost calculations can be extremely complex (see Vanbuel,

VSAT solutions in rural Kenya, 2007

2003), and it has been difficult to find models that enable poor communities to afford the undoubted potential that satellite technology can provide.

Energy and environmental sustainability

None of the above elements of the infrastructure required for ICT4D would be possible without electricity. This applies as much to the power needed to make a radio work, as it does to the energy requirements of a group of servers in the headquarters of an international bank. Unlike many other industrial sectors, ICTs are almost completely dependent on electricity. Other fuels, such as oil and gas, or the energy provided by flowing water or wind, cannot directly power a computer or television transmitter; they first need to be converted into electricity. It is not easy to obtain data on electricity availability globally, but consumption and availability are closely related, and Figure 4.3 therefore provides an important reminder of the dramatic differences between electricity supply in different parts of the world. Despite an almost six-fold increase in electricity generation since 1971, Africa still only produced around 540,000 GWh in 2004, representing a mere 0.62 MWh per person, compared with around 14.25 MWh per person in the USA (figures derived from http://www.iea.org). It is not only at a global scale that these issues make a difference, because in most poor countries there is also a marked difference between electricity supply in urban and rural areas; 60 per cent of households in Africa do not have access to their national grids (Bertolini, 2004, p. 3).

Without electricity there can be no ICT4D. Electricity can, however, be generated in a variety of ways, and recent innovations with solar power and the use of human energy, as with 'wind-up radios' (see for example http://www.freeplayenergy.com/), illustrate the diversity of solutions that are available, especially to most marginalised communities. Central to any consideration of electricity supply in the poorer countries of the world is not only its presence or absence, but also its reliability. For effective implementation of ICT4D programmes, it is essential that there is an appropriate and consistent source of electricity, and this usually means that back-up generators or some form of energy storage is required. Four main scales of electricity supply for ICT4D can be identified: national mains supplies, or the electricity grid; locally produced electricity from solar, wind, water and human energy; generators producing electricity from fuel such as oil or natural gas for specific organisations or institutions; and batteries, both rechargeable and otherwise. One of the fundamental difficulties in delivering ICT4D projects at a large scale is that such projects almost always rely on a mains supply. Using solar power at a single school level is a costly solution. Nevertheless, as Greenstar (http://www.greenstar.org) have shown, it is possible to build effective solar-powered community centres that deliver electricity, purified water, health and education information, and a wireless internet connection as illustrated in their projects in villages in Jamaica, India, Ghana and Brazil. One of the advantages that many of the poorer countries of the world located between

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Figure 4.3 *Electricity consumption per head, 2005 (source: OECD/IEA, 2007).*

the Tropics possess is abundant sunlight, and if photovoltaic technology can increase in efficiency and decline more rapidly in cost in the future then it may offer a viable solution for implementing ICT4D initiatives in locations not served by national grids. Few initiatives have yet experimented with the use of small-scale locally produced wind and water power to provide electricity to marginally located ICT4D programmes, but the potential of these sources of energy, especially in mountainous and coastal regions, is worthy of greater investigation. Critical to all such initiatives is the need to have energy-efficient batteries that can store the electricity that is not immediately used, thereby helping to provide greater continuity of supply. At a smaller scale, the Freeplay Foundation (http://www.freeplayfoundation.org) has been developing and implementing human-powered electricity generation, such as the Weza, a foot-powered portable energy source, that can be used to provide sustainable rural energy solutions for ICTs (see the case study 'Radio for education' on pp. 000–00).

Any discussion of energy would be incomplete without some mention of the environmental sustainability issues surrounding the use of ICTs. There is no doubt that the dramatic global increase in the use of ICTs has led to a considerable surge in energy demand. Moreover, many of the components used in computers are highly toxic and until recently little attempt has been made by suppliers to minimise their use or to initiate recycling programmes (Kuehr and Williams, 2003). Indeed, there have been very few rigorous attempts to analyse the total environmental impact of ICTs. Such research would need to factor in the costs of launching and decommissioning the satellites used for telecommunication purposes, apportioning the full costs of energy infrastructure provision, and the impacts that these technologies have had on human physical mobility through, for example, the use of video-conferencing instead of face-to-face meetings. Campaigning organisations such as AsYouSow (http://www.asyousow.org/sustainability/ewaste.shtml) have nevertheless recently begun to have an impact, with computer companies now beginning to provide recycling solutions for their hardware. Civil society organisations such as Computer Aid International (http://www.computer-aid.org) and Digital Links International (http://www.digital-links.org) have also begun to provide refurbished computers for use in poorer parts of the world, and there is clearly a demand for such products. Nevertheless, there is considerable debate about the costs and benefits of such initiatives. On environmental grounds, the use of refurbished computers prolongs the life of perfectly usable hardware, and thus helps to reduce the wastage resulting from the obsolescence caused by the rapid rate of technological innovation in the ICT industry. However, against this, it can be argued that the shipping of old computers from the richer countries of the world to the poorer ones is actually also shifting the responsibility for their eventual disposal to those who can least afford

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Radio for education

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The role of ICTs in enhancing education in Africa has received considerable attention in recent years, with much activity centred on how best to utilise the rapid expansion of computer and internet availability across the continent. Despite the clear educational potential of these technologies, many such initiatives have been influenced by a top-down, supply-led mentality and strong private-sector agendas, with the result that alternative and potentially more appropriate educational technologies have tended to be overlooked. This case study considers how educational development can be catalysed through radio, the ICT that currently has the greatest penetration levels across Africa.

Despite current efforts within African primary education to provide universal access, there are still significant challenges surrounding enrolment, completion rates and overall levels of attainment. The role of radio in providing education within such a context has traditionally been inhibited by two key barriers: the medium's inherent lack of interactivity, leading to the perpetuation of didactic approaches to teaching; and unreliable electricity supplies combined with the prohibitive cost of batteries, leading to a failure to access the most marginalised communities.

These longstanding constraints, compounded by the rise of other in-vogue technologies, have led to radio being somewhat ostracised within current ICT for education agendas. However, the Zambian Ministry of Education initiative Learning at Taonga Market (LTM) demonstrates that, when deployed within an appropriate framework, the radio remains a valuable educational tool in the 21st century. The programme has shown the potential to overcome the recognised limitations of the technology, offering widespread access to high-quality and low-cost education for both economically and geographically marginalised children. The effectiveness of LTM is due to the combination of two distinctive elements: the use of the interactive radio instruction (IRI) teaching methodology and the Lifeline radio.

The IRI methodology is dependent upon a central team of educationalists to design content for the daily radio broadcasts, and a mentor in each community to gather the children and facilitate the local learning environments. This combination develops the radio from a simple rote-learning device into a tool that promotes a student-centred approach based on a constructivist, dialogical pedagogy.

As a dual-powered device utilising both wind-up and solar technology, the Lifeline radio circumvents dependency on traditional sources of power, thus minimising maintenance costs and ensuring widespread and equitable access. The radio was developed by the Freeplay Foundation (*http://www.freeplayfoundation.org*, accessed 20 November 2007) for specific use in the humanitarian sector. It is now deployed in numerous educational contexts across Africa, and is popular because of its simplicity, durability and distinctive design.

LTM was launched with the objective of combining the potential of IRI and the Lifeline radio in order to provide access to good-quality education for the 800,000 Zambian children not currently attending school. Since its launch in 2000, over 160,000 children have received education through theprogramme. In addition to the curricular broadcasts, a daily life-skills session provides an opportunity for broader learning, encouraging behavioural change among the students and instigating wider discussion among community members. Exam results from Lusaka province in 2007 indicated a significant improvement in educational quality among LTM students compared with those in mainstream schools, leading to a decision by the Ministry of Education to expand the programme to supplement teaching in an additional 4,000 government primary schools during that year.

The scaling-up of ICT for education initiatives to operate sustainably at a national level remains a widespread challenge. However, the case study of LTM in Zambia demonstrates the potential for achieving this transition successfully when certain fundamental components are in place. Programmes must be demand-driven, employ appropriate technology and have support from both local community and government, remaining focused on the primary role of ICTs in education as catalytic tools for instigating progressive reform.

it, especially since older computer parts are also more likely to fail than younger ones. On the socio-economic side, there are likewise strong arguments that giving poor people the opportunity to learn how to use computers is of real benefit, regardless of the quality of the actual computers themselves. Much high-quality educational software, for example, can run on very basic computers, and does not require the use of the latest high specification and expensive machines. On balance, provided that the quality of the refurbished computers is of a high standard, and particularly where people in recipient communities enhance their own skills and expertise by undertaking the refurbishment work themselves, there does seem to be some value in such initiatives. However, as a report by SchoolNet Africa (2004) summarises, many well-meaning initiatives have failed because of faulty computers, a lack of planning, and poor quality of post-supply support. In contrast, where refurbishing and maintenance skills can be developed within Africa, where the schemes are coordinated and implemented coherently, and where in-school ICT capacity is explicitly enhanced, then they can indeed bring benefits to people who could not otherwise afford to access computers.

User interfaces and information sharing

People require some kind of physical interface if they wish to gain information and communicate with each other at a distance. Whereas in the past there were distinct types of interface for various such interactions, the advent of digital technologies has meant that single multi-functional devices now combine most of the required functionality. The use of fixed-lline telephones transformed traditional means of face-to-face communication, enabling people in the 20th century to communicate with others in any part of the world. Nevertheless, telephones were rarely used primarily to gain vast amounts of information; their fundamental purpose was to enable two people to communicate effectively together at a distance. In contrast, televisions were used to broadcast information and entertainment; few people ever imagined that they could be an interface for two-way communication. Today, Voice over Internet Protocol (VoIP) and wireless technologies have enabled computers to become hugely powerful interfaces both for the gathering of information and also for communication purposes (see for example http://www.skype.org). This convergence of technologies has had a profound impact on human society, but remains spatially constrained. For many of the world's poorest people, telephones, radios and computers remain distinct and separate. This section therefore continues to draw a distinction between these main types of user interface.

Telephones

Fixed-line telephones dominated the world of telephony during the 20th century. Although radio was in use as early as the 1920s to enable communication on trains and with aeroplanes, it was not until the 1960s that advances in electronics enabled the first primitive mobile phones to be produced. These operated in a specific zone, or cell, accessible from a base station. By the 1980s, the technology had advanced sufficiently for the first generation of commercial mobile phones to be produced, taking advantage of networks of cells and base stations situated relatively close together. Such phones, however, were extremely bulky, and it was not until the 1990s that second generation (2G) phones were introduced (commonly known as GSM), using different frequencies and much more advanced signalling between phones and networks, as well as improvements in battery design and circuitry that made them smaller. The subsequent dramatic rise in the use of mobile phones was enabled by the construction of numerous base stations to increase cell density and thus permit users seamlessly to access networks wherever they wanted to. The success of such mobile phones led to a plethora of new innovations and competing technologies, which in turn required a complex system of standards to be introduced to enable users to communicate effectively with each other. Most recently, third generation (3G) mobile phones have been developed to combine voice data with digital video and e-mail. These required the use of new radio frequencies, the licensing of which in many countries has been seen by governments as a source of substantial revenue generation. The consequent high costs of implementation, as well as uncertainties over whether users actually want the services provided, has therefore led to some delay in the worldwide roll-out of 3G telephony.

Over the last decade, mobile phones have transformed the world of telephony (Table 4.2), both technically and also socio-spatially (Taylor and Harper, 2003). The impact of mobile telephony has been greatest in regions that previously had the lowest levels of fixed-line connectivity. Thus, although Africa still has by far the lowest density of telephone subscribers, some 87.2 per cent of all telephone lines on the continent were mobile subscribers in 2006, compared with a mere 57.5 per cent in the USA. This indicates not only

Table 4.2 ***Fixed line and mobile telephone subscribers, 2005–2006***

	Total telephone subscribers per 100 inhabitants		Mobile phone subscribers per 100 inhabitants		Mobile subscribers as a % of total phone subscribers
	2005	2006	2005	2006	2006
Africa	18.48	24.32	15.34	21.77	87.2
Americas	86.14	94.72	53.04	62.27	65.7
USA	130.23	134.55	71.43	77.40	57.5
Asia	38.45	45.20	22.98	29.73	65.2
China	56.53	62.62	29.90	34.83	55.6
India	18.47	18.47	8.16	14.83	80.3
Europe	125.12	135.14	85.35	99.27	70.5
Oceania	106.55	109.33	68.78	73.43	66.5

Source: derived from ITU (www.itu.int/ITU-D/icteye/indicators/indicators.aspx#)
Note: Figures are as given by ITU in separate tables, and do not always necessarily compute accurately

the problems and costs of installing and maintaining fixed-line services in Africa, where theft of copper cabling has been rife, but also the huge demand that exists for such communication services. Table 4.2 also emphasises the very rapid changes currently taking place globally in the balance between fixed and mobile telephony. These generalisations, nevertheless, hide many spatial inequalities, and as Figure 2.2 highlights (p. 000), there remain huge differences in the density of mobile phone subscribers in different countries. Thus, in states such as Ethiopia, where the government tightly regulates the telecommunications sector, there were on average only 0.53 mobile subscribers per 100 people in 2005, whereas in South Africa the figure was as high as 71.6 subscribers per 100 people (http://www.itu.int, accessed 26 March 2007). Viewed from another perspective, the average annual cost of mobile telephony for a user in Ethiopia is approximately 1/10th of the average annual income, whereas in South Africa it is 1/150th (Vanbuel, pers. comm.). Furthermore, within most of the poorer countries of the world, rural areas still have much less accessibility than do urban areas, once again reinforcing the disadvantages between the urban rich and the rural poor.

The very rapid adoption of mobile telephony in many of the poorer countries of the world, and particularly in Africa, has given rise to much interest in its use for broadly defined development purposes (see for example Kukulska-Hulme and Traxler, 2005). Typical potential uses, for example, have been explored particularly with respect to the opportunities that they can provide for farmers to gather market information, for mobile banking, for the provision of health services, and in teacher education. However, despite such potential value, much evidence suggests that mobile phones as yet are still used primarily for social networking rather than for any more specific poverty elimination purposes. Souter *et al*. (2005, p. 8) draw five important conclusions about the use of telephones in Gujarat, Mozambique and Tanzania:

- they are very important in emergencies so that people can contact one another;
- they are used widely to maintain social networks, particularly within the family;
- 'they are valued more for saving money than for earning money';
- richer and better educated people place more value on phones than do poorer people;
- they were 'considered unimportant for information gathering'.

Although these conclusions relate to the use of telephones in general, and not just mobile phones, they provide a salutary warning for those who see this particular technology as offering significant potential for the elimination of poverty.

This is not, though, to suggest that enabling poor people to have access to telephony is not of value in itself. Social networking is of extreme importance to human empowerment, and the ability of poor people to use mobile phones for social and political purposes can be of great value to their sense of being and identity (see also Brown *et al.*, 2001). Socially, there is much evidence that the advent of mobile telephony has fundamentally changed the ways in which people interact with each other. In the past, people had to move to fixed locations in order to communicate at a distance by phone, whereas now they have the freedom to communicate anywhere that they have a signal. This has led to profound changes in social interaction, and to very different kinds of human movement in space. Furthermore, the introduction of text messaging on mobile phones has led to the emergence of entirely new modes of behaviour, especially among young people, who have developed many new and culturally distinct forms of communication (see for example Taylor and Harper, 2003; Castells *et al.*, 2007). The political use of mobile phones is especially interesting, because they can be used both by those seeking to impose the rule of law, as well as by those eager to engage in political protest against that law. The richer governments of the world thus see their tracing of the global flow of phone conversations as a permissible means to fight the so-called 'war against terror', whereas others see it as an infringement of individual human liberties. As with so many technologies, the ability of those in power to control and regulate their use suggests that ultimately the advantage lies with them rather than with those eager to use such technologies to create alternative social and political structures.

Computer technologies

The modern computer has until recently been one of the most powerful tools in transforming the ways in which we communicate, gain information and share knowledge. While computational machines have been in existence for centuries, it was only in the 1960s that the invention of integrated circuits and microprocessors paved the way for the rapid dissemination of home and workplace computers from the 1970s onwards (Ceruzzi, 2003; for timeline see http://en.wikipedia.org/wiki/Timeline_of_computing). Central to the success of this transformation has been the dramatic increases in memory and processing speed (see pp. 000–00). Three main types of device associated with modern computers are usually distinguished: the processing part of the computer itself; input devices; and output devices. Broadly speaking, the hardware necessary for a computer to function consists of the following: the motherboard, holding the central processing unit (CPU) and random access memory (RAM), as well as other parts such as the basic input/output system (BIOS); a storage device, usually known as a hard disk; a power supply and fan to keep it cool; video and audio cards in order to enable sound and visual displays; buses which transfer data or power between components; and a means of enabling the computer to interact with the internet, such as a modem. Input devices are becoming increasingly diverse, moving beyond the traditional mouse and keyboard, to include microphones, cameras, gaming sticks, tablets, image scanners and screens that also act as input devices. Output devices include screens, printers, loudspeakers or touchpads for people with visual impairments. Many of these can be integrated into a single notebook computer, but more often than not the computational, output and input devices remain separate, as with desktop computers that also require external power supplies.

While hardware provides the basic functionality of computers, it is the software that runs on them that enables users to take advantage of this. Most people have little knowledge of the processing functionality of computers, and their use tends to be restricted to five main functions: information gathering (most frequently on the internet, but also from data storage devices such as CDs or DVDs); communication (traditionally via e-mail, but now increasingly frequently through social networking sites, such as http://www.facebook.com, and VoIP); information processing (from basic calculations, to image processing, and database applications); the production of information and knowledge (as in the writing of reports, or graphic design and simulations); and entertainment (in the form of music, films and games).

The most important point to be made here is that the particular conjuncture of hardware and software can be configured very differently to serve the needs of varying users. Unfortunately, all too often users are provided with standardised hardware and software that may not actually be of direct benefit to their development needs. For example, almost all basic ICT training programmes such as the European/International Computer Driving Licence (ECDL/ICDL) (http://www.ecdl.com) focus largely on the provision of a standardised set of 'office' packages, such as word processing, spreadsheets, databases and presentations. While these are indeed relevant to business environments, they are invariably of little direct use to poor and marginalised communities. Teachers, for example, do not need to learn how to use the word processing functions of an office package in order to be able to use good educational software to help students learn. Likewise, Sugata Mitra's (2003) work on minimally invasive education has shown conclusively that young poor people can benefit from using computers placed in readily accessible places in their communities without any formal training at all (see the case study in Chapter 9, pp. 000–00, and http://www.hole-in-the-wall.com). Moreover, people with disabilities, including visual and hearing impairments as well as those who have difficulty controlling their fine motor skills, can benefit enormously from input and output devices designed to suit their needs, such as Braille readers and specially designed keyboards and mice. Unfortunately, because of the relatively small demand for such devices, they are much more expensive that the standardised hardware available to other users.

One distinction in the architecture or configuration of computer systems that is of particular importance in the field of ICT4D is that between what are known as 'fat' client and 'thin' or 'lean' client systems. Because of the relative cheapness of personal computers (PCs), most computer laboratories in schools, libraries, universities, businesses and community centres in the richer parts of the world effectively consist of a large number of fully functional individual computers, linked together by cabling to a central server that then provides connectivity to the outside world as well as other networking services. Most of the processing is actually done on the individual desktop or notebook computers, with data only being passed to a server for networking, and sometimes storage. This is what is known as a 'fat client' solution. However, for most uses it is not necessary to have large amounts of processing within all of the computers in a lab, and a single powerful server can do most of the necessary processing for a large number of 'dummy' terminals. These terminals need only contain an input (keyboard, mouse) and an output (screen) device, as well as a limited amount of processing sufficient to run a web browser or some kind of remote desktop software. They are therefore generally cheaper, and can be of much lower specification than the desktops to be found in most computer labs across the world. Such 'thin client' architectures therefore have much potential in delivering appropriate solutions in contexts where the cost of hardware is a major concern. Other benefits that thin client systems offer for development contexts include their lower energy costs, their ability to be used effectively in dirty environments because the terminals do not have moving parts, lower maintenance costs because everything can be managed from the server, and the fact that because the terminals are of low value they are less appealing to thieves. Despite these advantages, and the ardent advocacy of organisations such as NetDay South Africa (http://www.netday.org.za), it is surprising that not more thin client solutions are being promoted in Africa and Asia. In part this is because such solutions require careful and organised deployment and support, and work best where there can be institution wide implementation, which is not often possible in small-scale community-based installations.

Convergence and the new generation of mobile devices

One of the key features of the ICT industry over the last decade has been the rapid convergence in technologies. The latest generation of mobile phones and personal digital devices for example not only provide telephony, but also contain cameras, radios and calendars as well as having quite powerful computational abilities and connectivity to the web. Thus, in 2007 Nokia's advertising campaign for their recently launched N95 mobile phone described it as 'It's what computers have become' (http://shop.nokia.co.uk/invt/0027027, accessed 4 May 2007). Such technology nevertheless comes at a price, with the N95 costing £459 from Nokia at the start of 2008 (http://shop.nokia.co.uk, accessed 7 January 2008), compared with the cost of a

Dell Inspiron 6400 laptop at only £329 (http://www.dell.com, accessed 7 January 2008). In the not-too-distant future it is possible to imagine a single small combined device that will have all of the basic information and communication functionality that most people will need. To date, the key restrictions on most mobile devices have been the size of the screen and the difficulties of using the keyboard. However, external keyboards are already available, and as voice-controlled software improves, it is likely that inputting information will become much easier. More of a challenge is the problem of the screen size, but even this is becoming less of an issue, as shown in the quality of videos and movies on devices such as the latest generation of iPods from Apple (http://www.apple.com/ipod/ipod.html).

Already, there is a wealth of expertise on mobile- or m-learning (see for example http://www.m-learning.org; Attewell, 2005; Kukulska-Hulme and Traxler, 2005; Leech *et al.*, 2005), but much of this remains ambivalent in terms of its real development benefits for poor and marginalised communities. Enthusiasts are eager to show that it is indeed possible to use small digital devices such as mobile phones and PDAs to provide useful materials for teachers and learners, but their use has not yet caught on as swiftly as might have been expected. In part this can be explained by the findings of Souter *et al.*'s (2005) study which emphasise that people in Asia and Africa still tend to want to use their phones primarily for communication, rather than actually to gather information. It may also reflect quite simply the lack of relevant content and educational software that has as yet been made available for these devices. The size of the screens on these small devices, especially for those with poor eyesight, is nevertheless likely to remain a serious drawback to their wider use for learning purposes.

This problem of size can, however, be approached from another direction by thinking about reducing the size as well as the cost of notebook computers. The One Laptop per Child initiative (OLPC), launched by Nicholas Negroponte in 2005 with a group of colleagues from the MIT Media Lab (http://www.laptop.org), provides one such vision for the future (see also Intel's Classmate project http://download.intel.com/intel/worldahead/pdf/classmatepc_productbrief.pdf?iid = worldahead + ed_cmpc_pdf, accessed 4 May 2007). The OLPC initiative in part seeks to reduce the cost of specially designed laptops for children by purchasing very large numbers of parts at discounted prices. Initially, it was announced that the laptop would cost $100 but by April 2007 this figure was revised to $175, which has reduced its appeal. Although the OLPC project specifically claims that it is an education initiative rather than a laptop one, with its goal being 'To provide children around the world with new opportunities to explore, experiment and express themselves' (http://www.laptop.org/en/vision/index.shtml, accessed 11 May 2007), the pedagogic model upon which it is based is seriously flawed (Kozma, 2007) and its real educational usages in poor countries have not yet been sufficiently proven. Moreover, the cost of providing such laptops to every poor child in Africa would be prohibitively expensive, and there is a strong argument that such money could better be spent on training good teachers to inspire a new generation of African learners. Interestingly, India has rejected the OLPC project, and in May 2007 its Ministry of Human Resource Development announced that it was exploring the production of even cheaper laptops, costing an estimated $47 per unit, possibly coming down to only around $10 (http://timesofindia.indiatimes.com/TOIonline/India/HRD_hopes_to_make_10_laptops_a_reality/articleshow/1999849.cm, accessed 11 May 2007). If this price mark is indeed even approximately achievable, then there do seem to be very real possibilities for extensive deployment of a new generation of small but powerful user interfaces that could become of real value to poor people and marginalised communities. We urgently therefore need to be engaging much more pro-actively in exploring the potential of these hardware 'solutions', identifying how best they might serve the needs of such communities. We must also develop and share better understandings of the total cost of deployment of such technologies before foisting them on unsuspecting governments and educational systems.

Radios and television

Much of the ICT4D literature and practice, while espousing the notion that ICTs are indeed much more diverse than just the use of computers and the internet, has tended to ignore the real contribution that more traditional forms of mass media can make to contemporary development. Indeed, it is often the case that the most appropriate and effective means of communication can be radio and TV, particularly since they are generally most accessible for the poorest and most marginalised communities (Figure 4.2) (Buckley, 2000; Girard, 2003; Skuse *et al.*, 2004; Mozammel and Odugbemi, 2005).

The use of TV and radio for development objectives has not, though, been unproblematic (de Fossard, 1996). By definition, mass media has tended to be centrally driven, with the intention of broadcasting a particular set of message to a large number of intended recipients. Indeed, many radio-for-development initiatives in Africa and Asia initially drew their impetus from the use of radio programmes in the post-1945 period in Europe to encourage a particular path of social and economic change. Similar initiatives in the poorer countries of the world have, as Melkote and Steeves (2001, p. 268) comment, been 'criticized for (i) their trivial and irrelevant content; (ii) giving rise to a *revolution of rising frustrations* in developing nations; and (iii) increasing the knowledge gap between the advantaged and disadvantaged sectors of the population'.

National centralised public broadcasting has often been used to convey particular messages through which governments have sought to influence and control their populations. Indeed, the character of broadcasting largely reflects the character of the society that produces it. Centralised states, most notably the Soviet Union and fascist Germany, used film and radio directly and effectively in the 20th century to seek to impose the will of their leaders on the minds of their populations (Taylor, 1998). Nevertheless, all publicly or government owned radio and TV broadcasting does have this potential to convey only the messages that rulers want their people to here. As Barnett (2004, p. 251) has emphasised: 'Modern understandings of the relationships between media and citizenship have developed in a specific context in which broadcasting was institutionalized as an assemblage of technologies, organizations, markets and social practices that articulated two spatial scales of activity: the private domestic home and the nation state'. One of the most striking examples of the use of radio in recent times to mobilise people to do the will of their leaders was thus its use in the Rwandan genocide that took place in 1994. As reported by Fahamu (http://www.fahamu.org/rwanda.php): 'Prior to the genocide, radio stations and newspapers were carefully used by the conspirators to dehumanise the potential victims, Rwanda's Tutsi minority. During the genocide, radio was used by the Hutu extremist conspirators to mobilise the Hutu majority, to coordinate the killings and to ensure that the plans for extermination were faithfully executed' (see also http://news.bbc.co.uk/1/hi/world/africa/3257748.stm; and Windrich, 2000, for an Angolan example).

Nevertheless, as Buckley (2000, p. 180) has also emphasised: 'Democracy and communication are inextricably linked, so much so that the existence or otherwise of certain forms of communications can be a measure of the limits to which democracy itself has developed or is held back'. Where the mass media is independent from government control, and ensures a plurality of voice, it can do much to provide opportunities for effective democratic processes to emerge. Moreover, local and community radio can be used highly effectively not only to convey particular information messages but also to engage and involve people in beneficial development practices (see for example Mano, 2004; Papa *et al.*, 2000; Jayaprakash, 2000; Vaughan *et al.*, 2000a, b; Villaran and Caistor, 2000). In developing such programmes, it is crucial for script writers and producers to draw upon the advantages of radio as a medium, such as its basis in oral tradition, its appeal to the imaginations of listeners, and its ability to be heard en masse and individually at the same time. Likewise, they need to overcome problems with the medium, notably that most listeners tend to use radio as background, that it is usually only heard once, that there are some subjects that radio alone cannot teach, and that it can only use the medium of sound to try to create an impression of the scenes that are being represented (de Fossard, 1996).

It is often thought that radio is merely a one-way transmission of information and ideas, but the use of telephones and the internet have transformed the potential for interactivity in radio usage. This is typified in some of the initiatives that have sought to introduce community radio for empowering poor people. As Jewel (2006) has commented in the context of Bangladesh,

> Community Radio is radio for the people and by the people. The main objective of such a radio station is to enhance democratic process at a local level by giving voice to the voiceless. Also such an outlet helps in increasing diversity of content and information at the local level in order to promote culture. It also encourages participation, sharing information and innovation . . . It can reach people who live in areas with no phones and no electricity. Radio reaches people who can't read and write. It can be a main vehicle to distribute information, discuss issues and define our culture.
>
> (Jewel, 2006, p. 5)

(For a wealth of resources on community radio, see http://www.communityradionetwork.org, accessed 2 January 2007).

Reducing the costs of equipment and opening up licensing to the spectrum of broadcasting airwaves have enabled local communities to produce radio programmes that can be of real relevance to their needs, be they farmers in parts of rural India, or teachers in Africa (see UNDP and VOICES, 2004a, b). However, the origin of community radio in the illegal pirate radio stations of the 1970s has given rise to some concerns over its use (Sakolsky and Dunifer, 1998). Hence, the conditions under which community radio stations are emerging are generally being very tightly regulated by national governments. In the long run, though, it seems likely that the increasing use of podcasts and the ease of dissemination of digital broadcasting over the Web will lead to much more general acceptance of the value that community radio stations can provide.

The added realism provided by the visual dimension of television has also been used extremely powerfully in delivering empowerment and development-related programmes that move beyond the mere sound of radio. However, the costs of television production and broadcasting are much higher than those for radio. To produce a 15-minute radio-soap episode in Kenya cost around £800 in 2007, whereas to produce a high-quality 30-minute episode of a TV-soap cost around £20,000. Moreover, the costs of TV airtime are also very high, being £2,000 for a 30-minute slot for TV in Kenya as compared with Kenya Broadcasting Corporation's charge of around £800 for 15 minutes on their Kiswahili radio service. However, if the TV or radio programme is popular and relevant, the costs can be met by advertisers. The value of TV for conveying important development-related messages is particularly striking, especially since it can often be used to reach much larger audiences than radio. In Kenya, for example, three main TV stations compete for a seven million audience, whereas there are 48 FM radio stations competing for a 20 million audience.

The benefits of both TV and radio are well illustrated by the work of Soul City, which first began programmes on HIV/AIDS and mother and child health in South Africa in 1994, and by 2007 was regularly reaching some 16 million South Africans. Key factors in the success of Soul City have been its multimedia format, the drama 'edutainment' format that has been sustained over time, and its thorough development process grounded in local contexts (Scheepers *et al.*, 2004). Another example of the value of TV in South Africa has been *Yizo Yizo*, an educational programme first shown in 1999 which focuses on youth issues, and is described by its producers as 'a gritty, uncompromising television drama series set in a township school that has achieved record-breaking audiences and cult status among South Africa's youth. Rape, murder, prostitution, abuse, HIV/AIDS. Serious issues. We wanted to contextualize them for people with the power of music, laughter, friendship and glamour to match the gritty authenticity of the work' (http://www.thebomb.co.za/yizo1.htm; see also Barnett, 2004).

The value of TV and radio is not, though, only through the impact that it has among the world's poorer communities. Media events such as Live Aid in 1985 (Geldof, 1986) and Live 8 in 2006 (http://www.live8live.com), which it is claimed was watched by 3 billion people, have a very significant effect in raising issues associated with poverty in the minds of people living in the richer countries of the world. This, in turn, contributes to political campaigns, and to the policies adopted by donor countries with respect to development agendas. Nevertheless, the imagery and sounds broadcast on TV and the radio, as well as those used more widely in advertising campaigns, are far from neutral, and are chosen to represent the views of those producing the programmes. This was particularly well brought home a report by VSO (2002) that explored the impact of events such as Live Aid on the UK population's perceptions of development. It highlighted that: 'Many UK consumers retain an essentially one-dimensional view of developing countries. The stereotypes are primarily driven by images of drought and famine in African countries – "the Live Aid Legacy"' (VSO, 2002, p. 15). As the VSO (2002, p. 15) report went on to comment: 'While these stereotypes are not completely false, they are only part of the picture. They generate and reinforce a relationship of powerful giver and helpless recipient. This relationship pigeonholes and constrains developing countries, creating the impression of a one-way, rather than two-way relationship. In turn, this limits our capacity to learn and benefit from such countries and cultures'.

Individuals and communities: debates over software and content

Chapters 2 and 3 highlighted the contrasting logics of different approaches to development practice, and placed particular emphasis on the need to consider relative aspects to poverty as well as the currently more popular focus on economic growth as a solution to absolute poverty. These different approaches also underlie one of the fundamental conceptual distinctions in the use of ICTs for development, one that has crucial practical implications. At the heart of this debate is the way in which we conceptualise the value of knowledge, and whether it is something that should be individually or communally 'owned' (Figure 4.2).

This has particular resonance for any consideration of ICT4D, especially since the new technologies discussed in this chapter have the potential to make information much more accessible and more widely distributed than ever before. Two, often conflated, aspects need to be distinguished: the actual information *content*; and the mechanisms through which this is distributed, including both the *channel* and the *software*. Models and practices exist whereby each of these can be subject to payment, or can be free to end users. There is, though, as yet little agreement as to which options are actually best for different communities (see for example Rangachari, 2006: Yusof, 2007), in part because advocates of the different propositions usually base their arguments on very different premises and assumptions.

Software solutions

For the purposes of this discussion, the term software is used to refer to the programs that enable hardware, including not only computers but also phones and other digital devices, to function effectively. For long, software designed by programmers working for the private sector has been developed and sold by companies such as Microsoft (with its Windows operating systems) that have kept the programming code confidential. The operating systems and application programs that run on it, such as Microsoft Office, are sold at a profit to enable the programmers to be paid, new products to be developed and shareholders to reap financial benefit. In contrast, there has also been a parallel movement that has sought to develop software on a shared basis for the common good (Gay, 2002). This 'free software movement' was officially founded by Richard Stallman in 1983 when he initiated the GNU (GNU's Not Unix) Project, and it became fully functional in 1992 when Linux (developed by Linus Torvalds) was released as a completely independent and free operating system (Moody, 2002). If proprietary systems are essentially about economic gain, free software is much more of a social and ethical movement, and this distinction is one of the main reasons why advocates of these contrasting positions frequently seem to have difficulty in agreeing on any basis for reaching consensus decisions.

The creation of 'free' software has necessitated the creation of new types of license that seek to permit how people are allowed to use it. The Free Software Foundation has thus defined four freedoms:

- The freedom to run the program, for any purpose (freedom 0).
- The freedom to study how the program works, and adapt it to your needs (freedom 1). Access to the source code is a precondition for this.
- The freedom to redistribute copies so you can help your neighbor (freedom 2).
- The freedom to improve the program, and release your improvements to the public, so that the whole community benefits (freedom 3). Access to the source code is a precondition for this.

(http://www.gnu.org/philosophy/free-sw.html)

During the late 1990s, alternative models emerged, particularly the Open Source Initiative, which has not been so opposed to proprietary software, and has instead promoted the use of the term 'open source software' as an alternative to free software. In turn, FOSS (Free and Open Source Software) and FLOSS (Free/Libre Open Source Software), the latter ensuring the incorporation of a French dimension, have emerged as generic terms to refer to alternatives to proprietary software.

The critical question for those advocating the development and use of FOSS (see for example Ouédraogo, 2005) is how to generate sufficient revenue to cover the costs involved in developing the software. Sometimes this is done by providing services in support of the programs that have been developed, such as training or maintenance, but few such models have as yet been proven to be particularly profitable or sustainable. Much FOSS development is actually undertaken by programmers who generate income from other activities, even working for companies selling proprietary software, and treat their FOSS work as a 'spare-time' activity, thus in a sense self-exploiting their labour for the common good. There is extensive debate as to the relative advantages of open source and proprietary software. Advocates of open source point out that:

- it is much cheaper for end users than proprietary software, and therefore it is particularly relevant for poorer communities;
- it is less susceptible to viruses, because potential assailants are less interested in damaging a communal project;
- it is of potentially higher quality, because a whole community of developers is available to enhance it and solve any problems that emerge, unlike the case of proprietary software which is developed by a smaller number of paid programmers;
- it has the moral high ground, because it is developed and shared for the common good rather than individual profit; and
- those involved in the community are among the most gifted and committed programmers who are involved primarily because of their interest rather than any income that it generates.

In contrast, advocates of proprietary software argue that you get what you pay for, and that to develop high-quality software requires very considerable investment that must be financed through an appropriate market mechanism. Moreover, they also argue convincingly that certain highly specialist types of software, especially where secrecy is involved, can only be developed through focused research and development that must in turn be paid for.

In trying to resolve these apparently contradictory positions, it can be suggested that different types of solution are preferable in different contexts. A comparative study by bridges.org (2005), for example, has emphasised that many other factors than simply cost must be taken into consideration in reaching any decision, and local context and needs are crucially important. However, if an organisation, be it a small NGO or an entire country's education system, simply cannot afford licences for Windows operating systems, then a Linux-based alternative may well make a lot of sense. Likewise, with applications software, Open Office (http://www.openoffice.org) is a completely free multiplatform alternative to Microsoft Office. Recognising this threat to their position, but also determined to help reduce the digital divide, Microsoft announced the release of a cut-down version of its Vista operating system and Office software called the Microsoft Student Innovation Suite early in 2007, to be made available for students in developing countries for the sum of only $3 (http://www.microsoft.com/emerging/transformingeducation/MicrosoftStudentInnovationSuite.mspx). An alternative approach has been that adopted by Apple, which deliberately sought to bring together different development environments, and combined the work of its own programmers alongside the strengths of the FOSS movement in creating its Mac OS X operating system (see http://www.kernelthread.com/mac/oshistory). Crucial to the ability of users to work across several environments has been the incompatibilities involved in using different operating systems. As a result, regulators and indeed many application software developers have been keen to ensure consistency of standards across the industry, and those operating on behalf of consumers have also sought to limit the monopolistic tendencies of some global corporations. In one of the best known of these, the European Commission concluded in 2004 that Microsoft had broken European Union competition law, by leveraging its near monopoly for its operating system 'onto the markets for work group server operating systems and for media players' (European Commission, 2004).

Open content

A similar but distinct debate has arisen over the cost and means of production of content, usually with reference to educational content, but also of relevance to health-related content and indeed market information (see for example http://topics.developmentgateway.org/openeducation and http://www.hewlett.org/Programs/Education/OER). Traditionally, most published 'content' was developed by authors who entered contracts with publishers to produce books or articles, the income from which funded the publishing houses, defrayed the authors' expenses, and if the author was lucky might generate a small profit. However, by the end of the 20th century this model began to break down, with new ICTs enabling knowledge to be shared much more readily across the world, and a completely new international market in higher education provision also beginning to emerge. This has given rise to profound challenges to traditional models of higher education and knowledge production. In particular, authors and publishers have been forced to question the continued value of academic journals as the optimal means of knowledge dissemination for the former and as a source of profit for the latter. Likewise, universities have had to rethink their models of learning provision, with MIT for example leading the way in making the content of its lectures freely available on the Web (http://ocw.mit.edu; see also http://openlearn.open.ac.uk), and many institutions now providing the opportunity for students to undertake courses through distance-based modalities.

These changes have been brought to the fore in discussions about open educational resources (OER), and the value of collaborative authoring projects, enabled by the use of software such as wikis that allow many users to edit content (see especially http://oerwiki.iiep-unesco.org; but also Downes, 2007; Tapscott and Williams, 2006). As with FOSS, discussions concerning OER are similarly charged, and derive from fundamentally different conceptualisations of the world: on the one hand, the individualistic view, where knowledge is seen as a commodity, the purchase of which can give rise to greater earning potential and is thus a good investment; and on the other, the view that knowledge is a collectively produced social good, that should therefore be shared communally and indeed globally. The former is based once again primarily on economic arguments, whereas the latter is derived from rather different social and philosophical premises.

Three aspects of OER are particularly pertinent to their use in the context of ICT4D. First, there is already a wealth of content that is freely available on the Web for educational and health-related purposes. To be sure, not enough of this is specifically relevant and in a format usable by many poor people, and more work should be done in developing such resources by, for example, making them accessible in local languages. However, given the existence of so much material, it seems more important to develop effective mechanisms through which the good resources that already exist can be accessed in a user-friendly way by poor and marginalised communities than it is to fund the generation of yet more resources that people will have to sift through to find what they really want. Second, the facilitation of collaborative authoring projects through the use of software such as wikis provides a powerful mechanism through which shared understandings and communal knowledge creation can take place. Colleagues can now work together on knowledge creation from locations across the world, and if used creatively this can enable high-quality material to be developed that is of direct relevance to the needs of specific communities. The key advantage of wikis is that it is possible for others to benefit from the acquired wisdom of many authors and thereby to gain a richer understanding than that provided by one person alone (Tapscott and Williams, 2006; although see Keen, 2007, for a critical perspective). Nevertheless, a third issue with OERs concerns the mechanisms whereby authors are remunerated for their contributions. Various models exist for such provision (see for example Downes, 2007), but as yet most OER content development is enabled by people whose main source of income is generated from other activities. It is all very well encouraging groups of teachers or health workers to develop and share learning resources, but if this is to be done outside normal school or hospital hours, when many such people in poor countries have to undertake other forms of employment just to make a living, some form of additional remuneration must be provided. Likewise, there is a strong case for bilateral and multilateral donors to ensure that the results of any activities that they fund should be made available in the form of OER. Where donors finance the publication of textbooks in poor countries, for example, they should insist that these are made available in digital format for use in the diverse new learning contexts that are becoming increasingly accessible, even to some of the poorest communities.

Conclusions

This chapter has provided an overview of some of the more important technologies that can be used to address the information and communication needs of poor and marginalised communities. Four key issues can be highlighted in conclusion. First, there are many different technologies that can be applied to any one particular problem or situation. The most appropriate solution will depend on a wide range of factors, including cost, local context, infrastructural provision, the regulatory environment, and the specific needs of stakeholders and user communities. Far too often, externally generated solutions have been imposed without sufficient attention being paid to these crucial factors, and this is one of the main reasons why so many ICT4D projects have failed to deliver sustainable outcomes. Second, and linked to this, the provision of basic infrastructure, most notably electricity but also digital connectivity, is a fundamental prerequisite for the successful implementation of all ICT4D programmes. Without electricity even telephones and radios are useless. Far too often, ambitious ICT4D programmes have simply failed to recognise the huge obstacles that the lack of infrastructure creates for innovative solutions that can indeed help to empower poor people. Invariably, this is also caused by a concentration on technological solutions rather than on the real problems that need to be addressed. Third, the processes of convergence and miniaturisation have important implications for the sorts of hardware solutions that can best be developed for delivering effective ICT4D programmes. Once the complexities associated with screen size and the inputting of content are overcome, small low-cost multifunctional digital devices will offer enormous potential for those who wish to reshape the conditions that create poverty across the world. Finally, it seems likely that debates between those advocating open source and proprietary software solutions will persist for some time to come, since they are based on profoundly different sets of arguments and ideologies. While many would like to claim that knowledge should indeed be a global common good to which all should have equality of access, the reality of the early 21st century is that knowledge is increasingly becoming a commodity. Those seeking to engage in delivering ICT4D agendas that will truly bring equality of opportunity to poor and marginalised communities must therefore engage actively in arenas well beyond the realm of technology alone, and ensure that they can create powerful arguments that will shape the global social, economic and political agendas of the next fifty years.

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