3. Innovation systems and the learning process

3.1 Introduction – Social and technological components of learning

A central observation about ICTs is that these technologies offer new opportunities for social and economic transformation. In the industrialised countries, these transformations are evident in the way that new forms of learning are giving rise to innovative knowledge networks which facilitate the creation and exchange of information. This chapter discusses some of the changes affecting the management of technological innovation within firms and public sector establishments concerned with the scientific and technological innovation process. This chapter is concerned mainly with questions about how people in firms and public sector organisations are learning to organise and manage ICTs. It focuses on how ICTs are affecting the production of knowledge and its distribution, and on the impact of ICTs embedded in product and process innovations in the manufacturing sectors.

Illustrations are drawn from the experiences of both industrialised and developing countries. This chapter offers insight into the process of organisational learning and the importance of user-producer linkages in building social and technological capabilities. These linkages and the learning process are changing with the application of ICTs. The organisation of knowledge production is undergoing changes which may have profound consequences for established institutions as well as for the management of organisational change. In spite of the increasing use of ICTs to enable access to formal (codified) information, this chapter stresses the continuing importance of informal (tacit) knowledge in the innovation process.

The first main section (3.2) looks at the new modes of scientific and technological knowledge production which are beginning to emerge in the industrialised countries and considers their implications for developing countries. Section 3.3 considers the growing importance of linkages between users and producers and the way these are being affected by the application of ICTs. Section 3.4 examines the nature of the learning process for people in organisations when codified and tacit forms of knowledge are combined to generate new knowledge. Section 3.5 moves on to look at organisational learning processes in the context of the introduction of advanced manufacturing technologies and Section 3.6 illustrates some of the forms of industrial organisation which seem to be related to the effective use of ICTs. Section 3.7 takes up the important issue of skills and capabilities that firms need to acquire for productive use of these technologies giving special emphasis to skills involved in the management of technological innovation. The importance of trust is the subject of section 3.8 because of its role in alliances and partnerships among organisations that are providing the basis for people to learn and develop new capabilities. Section 3.9 provides a country case study (China) of the management of organisational change and technological innovation. The final section of the chapter, section 3.10, emphasises the types of knowledge that are needed to assess technology options, select innovative ICT applications and ensure that capabilities are built up to use them effectively.

3.2 Changes in the scientific and technological R&D process

The capacity to acquire and generate knowledge in all its forms is a critical aspect of the development process regardless of how that process is defined. The type of knowledge differs depending on whether a social, political, economic, technological, or scientific perspective is adopted. For example, some models of development concentrate on raising the average general level of education of a population, others stress the importance of a strong science base, while still others focus on technology transfer, that is, on adopting knowledge produced by others. Scientific and technological knowledge plays a very important role in the innovation process. It has been argued in recent years that the way in which scientific and technological knowledge are produced is changing quite radically (Gibbons et al. 1994). If there is a fundamental change in the 'mode' of knowledge production it is likely to lead to a reorientation of R&D practices and organisation. If the changes are pervasive across fields of scientific and technological activity, they will affect the research and innovation systems of both industrialised and developing economies, albeit in different ways.

The emergence of a new mode of knowledge production has profound implications for developing countries because of the tensions it creates with respect to the viability of existing institutions of science. In adopting the form of science which predominates in the industrialised countries, most if not all, developing countries have in some way embraced their institutional structures as well. As a consequence, many developing countries may find themselves 'locked in' to a mode of knowledge production which is increasingly less relevant to their specific technological and economic requirements.

The idea of a new mode of knowledge production is multifaceted and, therefore, difficult to describe briefly. According to Gibbons et al. (1994) the key change is that scientific and technological knowledge production is becoming a less self-contained activity. In many leading-edge areas of research, several different skills are required in order to solve problems. In addition, scientific knowledge production is no longer the exclusive preserve of special institutions such as universities from which knowledge is expected to spill over, or spin-off, to the benefit of other sectors. Knowledge production, its theories, models, methods, and techniques, has spread from academia and is now carried out in many different types of institutions. It has become a much more socially distributed process. Knowledge production has always had this characteristic to an extent, but the key feature of today's 'knowledge societies' is the rapid broadening of the production process on a spatial and institutional basis. The number of sites actively engaged in generating knowledge resources is multiplying rapidly. The new mode of socially distributed knowledge production has five principal characteristics.

- There are an increasing number of places where recognisably competent research is being carried out. This can be demonstrated by consulting the addresses of the authors of scientific publications. Change is taking place so quickly that the full extent of the social distribution of knowledge production is probably no longer fully captured by the printed word.
- These sites communicate with one another and, through this process, broaden the base of effective interaction. The stock of knowledge is derived from an increasing number of flows from various types of institutions that contribute to, and draw from, the stock of knowledge.
- The dynamics of socially distributed knowledge production lie in the *flows* of knowledge and in the shifting patterns of *connectivity* amongst these flows. Although the connections may sometimes appear to be random, in the new mode of knowledge production they move with the problem context rather than according either to disciplinary structures or the dictates of national science policy.
- The number of interconnections among knowledge producers is accelerating, apparently unchannelled by existing institutional structures, partly because these connections are intended to be functional and to survive only as long as they are useful. The ebb and flow of connections follow the paths of problem interest.
- The socially distributed knowledge production system is growing but it does not appear to be following the institutional patterns that have characterised science in the past. New sites of knowledge production are continually emerging and, in their turn, providing intellectual points of departure for further combinations of researchers. The emerging socially distributed knowledge production system appears to be characterised by a potentially exponential increase in the density of communication.

Research practices are changing fundamentally but the changes are not uniform across the whole range of research activities. However, when the changes described above occur together, the new practices have sufficient coherence to define a new mode of knowledge production called Mode 2 (Gibbons et al. 1994). Research practices in Mode 2 knowledge production differ from those that operate in the disciplinary structure of science which can be labelled as Mode 1. In Mode 2, problems are formulated and research is carried out in the problem solving context involving a complex interplay amongst specialists, users and funders. Research continues to be carried out in universities and in government and industry laboratories, but it is also, and increasingly, underway in research institutes, think tanks, consultancies, and in small firms supported by venture capital, for example, biotechnology and software firms.

Expertise in Mode 2 is configured around a particular problem, but the expertise itself may be drawn from a much wider range of backgrounds and institutions than in Mode 1. Mode 2 configurations tend to be organised in flat hierarchies and to have a relatively transient existence. The most interesting and intellectually challenging problems tend not to emerge from within disciplines, and research findings are less likely to be reported through the channels of communication that operate in Mode 1. The new ways in which research agenda are constructed and results communicated have major implications for all universities because generally they see themselves as the guardians of Mode 1. They define 'good science' in the terms that characterise Mode 1. The emergence of Mode 2 sets up different criteria of problem definition and of excellence in performance.

The new mode of knowledge production implies special problems for research in the developing world because the institutions which support science tend to be modelled on those of a former colonial power where it was assumed that there is a separation of the production of knowledge from its application and that 'open science' generates knowledge which can be passed through open exchange. For example, in Mode 1, specific types of institutions, universities and government laboratories are seen as producers of knowledge, while firms and other public institutions, such as the health services, are regarded as users of knowledge. In Mode 1 it is often assumed that difficulties in connecting the producers with the users of knowledge should be overcome by setting up technology transfer institutions of various kinds.

But in Mode 2, much leading-edge research is carried out in the context of application. In this process knowledge producers and users interact intensively in a process of negotiation. Until this process of negotiation occurs, no research is initiated. Access to this negotiation process is mainly the result of a recognition of specific expertise. For most industrialised countries, the problem is to access this process using whatever modes of communication are feasible including ICT-supported knowledge networks. In addition, in Mode 2, there may be a greater tendency for knowledge generation to pass from organisations committed to disclosure, to those committed to appropriating knowledge for profit, suggesting a factor which may exacerbate the exclusion of researchers in developing countries.

Researchers operating in the science systems of developing countries may be at a disadvantage in accessing various problem solving contexts. On the positive side, research in the context of application (Mode 2) may release developing countries from the need to create huge establishments of human capital devoted to pursuing a research agenda that has been set by others and structured along disciplinary lines. Mode 2 knowledge production requires a smaller, more specialist, scientific establishment which is skilled at making contributions to collective problem-solving efforts. On the negative side, problem contexts are more complex and developing countries may not be perceived as having sufficient expertise.

There is a tension here for developing countries because participation in Mode 2 requires both more and less specialisation. It requires more in that scientific and technological expertise within a country must be able to accommodate a wide range of contexts. It requires less specialisation in the sense that researchers need a wide range of generic skills. This is a difficult balance to maintain and it requires the identification of teams and partnerships to enhance the prospect of generating useful research results.

There is little evidence that Mode 2 is emerging in the developing world. Mode 1 remains dominant, in part because many national economic development plans that depend on foreign aid require countries to establish the types of Mode 1 scientific institutions that exist in the industrialised world. Many donor organisations insist that developing countries continue to build up establishments to match the 'best in the West'. This is an expensive option and it is not clear that this strategy is in tune with the changes in knowledge production which characterise Mode 1.

One locus for change consistent with Mode 2 knowledge production may be the universities. Meeting demand for higher education in the developing countries in the standard way through discipline-based universities is very expensive and governments are looking for less expensive alternatives. In a situation in which demand for higher education is fragmenting, no university is likely to be able to meet this demand entirely from within its own resources. Universities in developing countries are likely to need to seek partnerships of the Mode 2 kind to support teaching as well as research.[1]

If the scientific and technological base in developing countries is to engage in effective knowledge production in the context of application, people will be needed with the expertise to work in the way that characterises Mode 2. This process may be helped by efficient use of ICTs to enable researchers in these countries to develop a greater awareness of the range of expertise that exists world-wide and the partners with whom they might effectively combine to generate new knowledge. 'Knowledge networks' are increasingly spanning national boundaries and linking researchers in the industrialised and developing countries. Those who can engage in the new mode of knowledge production and who have access to global networks at relatively low cost are likely to be advantaged over those for whom such access is unreliable or costly. All these changes in the knowledge production process, and especially the trend toward knowledge production in the context of application, mean that the scientific and technical communities in developing countries need access to appropriate network infrastructures. They also need incentives to engage in international collaboration so that they can access the vitally important negotiation processes that lead to research.

The impact of ICTs is affecting the foundations of the 'culture' of scientific and technical knowledge production (Hawkins 1996). The use of ICTs to support scientific and technological research is influencing the way scientific and technical work is organised, the way it is operationalised, and the way it is evaluated. The potential exists for ICTs to be used to encourage diversity in the scientific and technical community by permitting more people to work in their own localities, and to develop research agenda that draw on local perspectives, experiences and conditions. For this to occur, however, institutional structures must evolve in a favourable way. Observers have pointed to the potential for conflict between the scientific community's interest in open networks and industrialists' interests in the protection of technological knowledge through the intellectual property rights regime. Others have noted that ICTs themselves do not create jobs, educate people or generate new knowledge. They can only contribute to the broader processes of learning, changes in work organisation, scientific and technological education, and the quality of life.

For the scientific and technological communities in developing countries, ICT-based research networks raise issues including: the balance that should exist between the requirements of the scientific and technological research community for open access to the most current scientific information and the rights to intellectual property held by various stakeholders; how to ensure that the knowledge generating communities in all countries have access to knowledge resources on reasonably equitable terms; how to allocate the costs of access to national, regional and global networks among various parts of the scientific and technological community; and how to ensure that scientific and technological research policies are linked with those for telecommunications, education, and industrialisation.

There is little dispute that scientific and technological research training is essential for the development process. Today, 'highly efficient technologies, even low cost technologies and technologies adapted for local use, tend to contain a large amount of research based knowledge' (Thulstrup 1994: 2). This is particularly so in the case of advanced ICT-based systems. The initiation of new learning processes in the public and private sectors is a prerequisite for effectively using these technologies.

3.3 Building learning capabilities

The full economic benefits of information technology depend on a … process of social experimentation and learning which is still at an early stage (Freeman and Soete 1994: 42).

The diffusion of ICTs is being accompanied by major changes in the systems of relationships between the producers and users of goods and services. These changes go beyond the changes in the mode of scientific and technological knowledge production discussed in the previous section. They reach into every branch of industrial production. Advanced digital ICT-based systems appear to be strongly associated with a 'paradigmatic' shift from older to newer modes of production of goods and services. Table 3.1 shows a comparison of the main characteristics of the older 'Fordist' or mass production mode with the emerging new ICT-based production mode. The widespread diffusion of advanced digital technologies and the availability of cheaper and growing computing capacity are speeding up a major shift in the 'techno-economic paradigm' (Perez 1983; Perez and Soete 1988).

The social and economic impacts of this shift to the new 'ICT paradigm' are very uncertain for all countries (Freeman and Perez 1988). The changes in the organisation of production in local and global markets that are accompanying this shift are occurring at different speeds and with different consequences in the industrialised and developing world. Since ICTs are only beginning to be used in the least developed countries, the social conditions and modes of organisation necessary to produce benefits cannot be inferred directly from empirical studies in these countries. The best option is for these countries to look at the experiences of countries that are further along the learning curve in the context of their own particular circumstances. Insights can be derived from the experiences of suppliers and users in their organisational settings in other developing countries.

ICT diffusion and implementation require complex interactions between technological, economic, social, and political forces and selection from combinations of innovations. Knowledge and learning capabilities are strategic resources in this context (Cassiolato 1996). The traditional literature on the diffusion of technological innovations tends to overlook the tendency for suppliers to benefit from the learning experiences of users (Clark and Staunton 1989). Recent research has shown that new technology diffusion and development processes are closely intertwined (David and Olsen 1984; David 1985; David and Bunn 1988). Technology diffusion rates can be explained by signals that motivate firms to overcome information asymmetries and to acquire the knowledge essential for the adoption of an innovation. In many cases, advanced users help to pull through innovations and generate further innovations that improve the new technology (von Hippel 1988). Thus, diffusion and development often occur simultaneously within competitive market economies (Metcalfe 1986).

Table 3.1 - Changes in techno-economic paradigm

'Fordist' Old	'ICT' New
Energy-intensive	Information-intensive
Standardised	Customised
Rather stable product mix	Rapid changes in product mix
Dedicated plant and equipment	Flexible production systems
Automation	Systemation
Single firm	Networks
Hierarchical management structures	Flat horizontal management structures
Departmental	Integrated
Product with service	Service with products
Centralisation	Distributed intelligence
Specialised skills	Multi-skilling
Minimal training requirements	Continuous training and re-training
Adversarial industrial relations; collective agreements codify provisional armistices	Moves towards long-term consultative and participative industrial relations
Government control and planning and sometimes ownership	Government information, regulation, coordination, and 'Vision'
'Full employment'	'Active Society'
Emphasis on full-time employment for adult (16-65) male workers	More flexible hours and involvement of part-time workers and post-retirement people

Source: Based on Perez, C. and Boyer R. in Freeman, et al. (1991).

Social, economic, and political selection processes linked to the diffusion process shape the use of innovative technologies. The interactions between suppliers and users, and a relatively sophisticated pool of technical skills in the surrounding environment, are important elements in the technology development process. The interactions between suppliers and users have two major implications. First, collective learning arising through inter-firm links in the early stages is more likely when open (rather than proprietary) systems are emerging. Second, the competitiveness of suppliers is linked closely to the competitiveness of the technology-using firms (Perez 1988).

The technology user as a creative contributor to the innovation process is very important in the case of ICTs. Users of ICTs in developing countries need to be able to imaginatively develop and modify the technologies they use. If user-producer interaction is essential to the innovation process, then there is a need for a growing presence of creative producers (not just users) in developing countries. Although, many developing countries, and particularly the least developed, are unlikely to play the role of producers of ICTs, the network character of ICTs means that to be an effective user, these countries do need to acquire skills and capabilities that go beyond those received through the import of sophisticated machinery and hardware (Freeman 1994). In order to become an efficient user of ICTs, firms (or countries) also have to acquire the relevant knowledge through an interactive process of learning-by-innovating. Raphael Kaplinsky has observed that, in the case of the use of automation technologies, the adoption of ICTs by firms in developing countries may be hampered by the absence of any local capacity to produce them.

... unless all, or most of the "electronic jigsaw" is in place, the systemic advantages of automation are difficult to capture. In the IACs [industrialised advanced countries], the diffusion of these jigsaw pieces is occurring for a number of reasons, including product-enhancing characteristic (as in the development of CNC machine tools), factor price considerations (word processors save on expensive secretarial time) and material savings (energy control devices). In LDCs [less developed countries], the factor price considerations are of muted importance ... [and] hence ... in some parts of the Third World only those technologies associated with product characteristics are diffusing. This obviously poses obstacles for longer-run systemic competitiveness (Kaplinsky 1988: 8).

In addition, because proximity to local markets continues to be crucial for the successful development and diffusion of many ICT products during the initial take-off period, the requirements of developing country markets are likely to be addressed only after the new technologies have matured (Cassiolato 1992).

In spite of the disadvantages facing many developing countries, a shift in the emphasis of national ICT strategies away from diffusion and toward the build-up of user capabilities is likely to permit 'user' innovation to occur. This kind of shift in technology policy has been characteristic of policies in the industrialised countries since the late 1980s: 'IT diffusion actions were in place (in the early 1980s), but they commanded modest resources and limited attention. In the latter part of the 1980s, however, the policy focus shifted increasingly to the diffusion (use) side' (Hanna et al. 1995: 48).

As a result of user innovation, ICT-using firms and institutions in the developing countries may be adopting ICTs in ways that are more efficient than some of their more developed counterparts (Cassiolato 1992), or at least at the same efficiency level (Coutinho 1995; James 1994; OECD 1993a). For example, strong user-producer relations led to very efficient production of banking automation goods and systems in Brazil. Achieving technological capabilities through a process of innovation/diffusion fostered by user needs also proved to be cost-effective (Cassiolato 1992). Even critics of Brazilian ICT policies acknowledge that the banking automation systems developed in Brazil are less expensive than their equivalents available internationally (Frischtak 1990). Case studies in Brazil show that banks successfully incorporated specialised personnel in their business, that is, electronics engineers who gradually acquired the skills to design and implement automation strategies. Institutional learning occurred as banks perceived the importance of ICTs and the engineers acquired the tacit knowledge of banking activities. They were able to transform this tacit knowledge into knowledge embedded in ICT systems. In contrast, retail firms in Brazil regarded specialised human resources as a cost. Automation decisions were taken by people with tacit knowledge about the retail business but no capacity to maintain a dialogue with technical people, and, as a result, interaction was impossible.

The successful diffusion of ICTs involves a process of collective and multidisciplinary, and dynamic learning. This encompasses the capabilities to use and to produce the technologies since relationships between users and producers are defined at the local level. Therefore, the domestic capacity to exploit ICTs lies in the particular mix of capabilities that it is able to generate for producing or using the technology. This defines a country's potential for exploiting *learning-by-doing* and *learning-by-using* processes. The learning processes are dependent on local action related to planning and organisational capabilities, 'managerial skills and entrepreneurship', human capital development, and strategies for generating large investments in telecommunications (Mody and Dahlman 1992).

Most developing countries cannot expect to cover all the components of the ICT sector. However, this is not crucial since the components, such as PCs, are becoming standardised. The critical issue for a national ICT strategy is to assess the importance of certain kinds of user-producer linkages in key segments of the industry and to encourage selected new capabilities in these areas.

3.4 The 'learning economy', ICTs, and tacit knowledge

The capacity of a national (or regional) system of innovation for building the capabilities required to take advantage of ICTs is a reflection of the nature of the 'learning economy' that exists in developing countries. Learning capacity is related not only to the sophisticated use of ICTs to access global stocks of knowledge, but to the characteristics of the communication process among people involved in the innovation process. For example:

... studies ... uniformly demonstrate that the way in which technical information gets communicated to those charged with solving technical problems is neither through formal computer-based scientific information or data retrieval systems, nor through news releases or technical briefings. Rather it is through people-to-people communication (Roberts 1980: 7).

ICTs should not be regarded as a potential substitute for human skills or tacit knowledge. Nevertheless, the use of ICTs can offer an important complementary component of the national information infrastructure leading to capability building and enhanced learning throughout the economy. Bengt-Åke Lundvall and others have suggested that the current phase of economic development is one in which knowledge and learning are more important than in any other historical period (Lundvall 1996a). This is because, regardless of the current capabilities of industrialised and developing countries, in the 'learning economy', individuals, firms, and even countries will be able to create wealth and obtain access to wealth in proportion to their capacity to learn.[2] This perspective holds that 'there is no alternative way to become permanently better off besides the one of putting learning and knowledge-creation at the centre of the strategy' (Lundvall 1996a: 2).

This means that broad definitions of knowledge and learning are needed. Wealth-creating knowledge includes practical skills established through learning-by-doing as well as capabilities acquired through formal education and training. It includes management skills that are learned through practice and insights generated by R&D efforts (see Box 3.1). In the 'learning economy', tacit knowledge is as important, or even more important, than formal, codified, structured and explicit knowledge.[3] Learning processes occur within all economic activities including R&D, marketing, production, and development.

Between the extremes of generic (codified) knowledge formulated in ways that can be accessed by anyone assuming a certain level of literacy and tacit competence that can be shared with others only through social interaction, there are mixed forms of knowledge.

How do these mixed forms of knowledge change with the ICT revolution? It is conceivable that the limitations on the transferability of tacit knowledge might be overcome by embodying it in products, process equipment and software systems such as business information systems and expert systems. However, the automation of human skills has proved to be successful only for relatively simple repetitive tasks that take place in a reasonably stable environment. There is also some evidence that firms which have over-emphasised the use of automated business information systems in their decision-making processes have been less than successful (Eliasson 1990).[4]

Box 3.1 - What is tacit knowledge?

Should firm A take over firm B or should it leave things as they are? To make such a decision involves the processing of an enormous amount of information and attempts to analyse a multitude of relationships between ill-defined variables. Guesstimates and hunches about future developments are crucial to the outcome. Evaluating the human resources in the other firm is a complex social act. There is no simple arithmetic to refer to (depending on future developments 1+1 may sum up to -2, +2 or even +10). It is obvious that the competence needed in this case is not easily transferred either through formal education or through information systems. It should also be observed that the decision is unique rather than one in a series of very similarly structured problems. Attempts to design formal decision models to cope with this kind of problem will not be meaningful and the knowledge remains tacit and local. The competence of business leaders can be learned but the learning will typically take place in a kind of apprenticeship relationship where the apprentice or the young business administrator learns by operating in close cooperation with more experienced colleagues (Lundvall 1996a).

The introduction of partially automated systems does not necessarily lead to the disappearance of tacit knowledge (Nonaka and Takeuchi 1995). The main impact of these applications is a speeding-up of specific phases of the innovation process rather than any reduction in the importance of tacit knowledge. This speed up may, paradoxically, increase the demand for tacit skills because there is a greater need to analyse and to react to a complex and rapidly changing flow of information.

ICTs can be used to reinforce human interaction and interactive learning. For example e-mail systems connecting people with common local knowledge can have this effect, and broad access to data and information for employees can further the development of common perspectives and objectives for the firm. Information can be reduced to 'bits' and put into a computer but tacit knowledge cannot be transformed into information, at least not without changing the content of the knowledge. The introduction of tacit knowledge, including shared tacit knowledge rooted inside firms or in local knowledge-intensive networks of firms, has an impact on global competition and firms are increasingly exploiting their specific knowledge assets all over the world (Lundvall 1996a).

An optimistic scenario for developing countries in the face of the diffusion of ICTs envisages a massive transfer of tacit knowledge into information systems giving these countries access to new process technologies and products developed in the industrialised countries both rapidly and at low cost. In theory, this would lead to an acceleration of the catching-up process and a reduction in global inequalities. However there are two less optimistic

Table 3.2 - The potential contribution of advanced manufacturing technologies to improved competitiveness

Problems in manufacturing	Potential contributions of AMT
Introducing new products on schedule	CAD/CAM shortens design lead time - tighter control and flexible manufacturing smooths flow through plant and cuts door to door time
Producing to high quality standards	Improvements in overall quality via automated inspection and testing, better production information and more accurate control of processes
Inability to deliver on time	Smoother and more predictable flow through design and manufacturing stages makes for more accurate delivery performance
Long production lead times	Flexible manufacturing techniques reduce set-up times and other interruptions so that products flow smoothly and faster through plant
High and rising material costs	Integrated production management systems (MRP2) reduces inventories of raw materials, work-in-progress and finished goods
Poor sales forecasts	More responsive computer-based systems can react quicker to information fluctuations. Better database permits more accurate forecasting

Source: Bessant (1996).

scenarios (Lundvall 1996a). The first is that access to the new knowledge is limited by the absence of capabilities to master the language and codes associated with ICTs. In this case access would be gained only by countries and firms with an appropriately trained labour force. The second scenario is more complex. In this case, tacit knowledge would play a major role but the application of ICTs would speed up the rate of economic change and stimulate the need for rapid learning, that is, the development of a 'learning economy' would be essential for developing countries. In this case the strategies for organisational learning, managing inter-firm relationships, and entry into the international or Global Information Society would be crucial.

There are likely to be different approaches depending on the institutional conditions in each developing country. A strategy which attempts to emulate the success of the newly industrialising countries in South East Asia often appears to be attractive as a basis for establishing a 'learning economy' because of their economic success in recent years. However, as noted in Chapter 1, it is not clear that this experience is replicable today. Organisational learning is possible if there is a substantial movement of people between the developing countries and the countries with some experience in practising strategies appropriate to the learning economy. Even when this is achieved, however, the importance of the local knowledge base and its integration with development strategies involving the application of ICTs should not be underestimated. Successful strategies in developing countries are likely to be those which give the greatest attention to the combinations of learning strategies that are promoted and to the way ICT applications are used to complement, rather than to replace, informal learning and technological and social capability building.

Information does not just "flow". Information must be coded, decoded, transmitted, comprehended. In an international economic, S&T, and socio-environmental setting this transmission and communicative requirement is ***very*** *complex and not well understood (Whiston 1997: 8).*

Learning occurs on an economy-wide basis and within, and across, organisational boundaries. The following section draws lessons about the learning process from the application of ICTs in advanced manufacturing technologies. Section 3.6 looks at some of the characteristics of the industrial organisation of the use of ICTs.

3.5 Organisational learning and advanced manufacturing technologies

Successful adoption and implementation of AMT requires considerable learning on the part of organisations. Whilst some of this can be facilitated by the provision of traditional training inputs, such as those offered by equipment suppliers, the general message is that a much broader spread of support is required (Bessant 1996: 40).

Advanced manufacturing technologies (AMT) refer to a 'bundle of technological opportunities which are opened up by the application of information technology but ... include in this bundle the organisational "good practices" which have emerged in parallel with IT developments' (Bessant 1996: 1). Organisational learning on a continuous basis is needed to benefit from these technologies as well as investment in hardware, software, and human resource development (Leonard-Barton 1995; Pisano 1996). The increasing globalisation of manufacturing and services is accompanied by changes in competitive priorities away from non-price factors and there are strong pressures to offer a wide range of products at low cost and of high quality. Global markets are also characterised by increased numbers of suppliers and declining trade barriers in many sectors (Bessant 1996). AMTs are expected to contribute to strengthening firms' competitiveness and the expected contributions are shown in Table 3.2.

AMTs offer opportunities to replace manual monitoring and control functions by automated processes. They enable integration by linking functions into systems, offering the potential for producing a greater variety of products, and a basis for the introduction of organisational innovations leading to greater flexibility, quality, and customer focus. They also can be used to support networking among locally and globally cooperating firms.

Early experiences with AMTs such as computer-aided-design/computer-aided-manufacturing (CAD/CAM), flexible manufacturing systems (FMS) and other applications, such as robotics and integrated computer-aided production management, have demonstrated that they must be located within a coherent business strategy and accompanied by relevant parallel organisational changes if they are to be implemented successfully.

The roles of people and organisational processes are critical to the successful introduction of manufacturing innovations. Organisational learning is the process through which organisations acquire tacit knowledge and experience. This occurs through individuals and their beliefs and actions which shape the organisation's view of the world and give rise to particular forms of action. Organisational learning involves a continuous cycle of searching leading to new experiences, the diffusion of these experiences, and the emergence of shared understandings.

The learning process also involves experimentation, experience, reflection, and conceptualisation. When the cycle of learning is incomplete, the benefits of AMTs are very difficult to capture. Many firms in the industrialised countries have been successful in completing this cycle and firms are now giving priority to the need to build a 'learning capacity' within the organisation (Cohen and Levinthal 1990). The necessary knowledge is unlikely to be available in formal (codified) form and so it cannot be acquired by formal education and training, for example, using ICT supported education tools.

The cycle of 'continuous improvement' provides a means of strengthening learning capacity through a repeated cycle of action, experience, and review; evaluations building on measurable performance parameters; the capture of information resulting from experiments; the presence of an experimental climate that does not punish failure; the display and communication of the results of success; encouragement of continuous challenges to the status quo; and the high valuation of alternative perspectives on problems (Bessant and Caffyn 1997).

Organisational learning can take the form of a simple adaptation of existing skills and organisational behaviours or radical changes when integrated production information systems are introduced (see Table 3.3). Integrated systems can reduce lead times, stimulate quality improvements, allow greater flexibility, and generate cost-savings in terms of inventory stock.

If these types of organisational learning are introduced in isolation they may result in an initial period of enthusiasm, but this is likely to be followed by abandonment. Alternatively, if the changes are introduced as part of a cycle of learning they are more likely to produce major cultural shifts across the whole organisation.

At the firm level, successful organisational learning to benefit from AMTs requires (Bessant 1996): learning and adaptation on a continuous basis; training and development to be treated as an investment rather than as a cost; time and resources being devoted to developing an organisational context which permits innovation; establishing and reinforcing a learning cycle linking codified knowledge with tacit knowledge; formal training by equipment

Table 3.3 – Types of organisational learning

Technique	Description
Total Quality Management (TQM)	Collection of techniques aimed at high involvement in monitoring and assuring quality, with emphasis on zero defects, customer focus, and continuous improvements.
Lean manufacturing	Collection of techniques focused on low/no waste manufacturing. Emphasises team working, continuous improvement, waste reduction.
Continuous improvement	Techniques designed to enable high involvement in incremental innovation.
Cellular/focused manufacturing	Grouping of operations focused on particular customer/product segment. Emphasises team working and continuous improvement.
Just-in-time	Originally based on Toyota Production System, the term refers to low waste techniques aimed at delivering the right quantity and quality just in time for it to be used in the next stage in the manufacturing process.
Concurrent engineering	Early involvement approaches designed to reduce problems due to inter-functional barriers.
Supplier partnerships	Close, cooperative relationships with suppliers can yield benefits in terms of faster, more reliable deliveries, lower inventories and improved quality. Emphasises joint problem-solving, lean principles.

Source: Modified from Bessant (1996).

suppliers complemented by common understandings of why changes are being introduced; training using classroom and 'on the job' opportunities; training 'just in time' to ensure connections are made between theory and practice; and an emphasis on core skills and enabling abilities (working cross-functionally, team working, monitoring, measuring and engaging in continuous improvement). These factors in successful organisational learning are found in case studies of different types of firms across industrial sectors. They point to the importance of lifelong learning, a feature that is central to the capacity to cope with challenges presented by ICTs.

Training at the firm level needs to be complemented by continuing education opportunities to upgrade and broaden skills and enabling abilities; the provision of opportunities for experiential learning through secondment programmes; awareness programmes raising support for companies; incentives for learning rooted in local cultures and firms; the use of bench-marking programmes to facilitate the transfer of knowledge between firms and sectors; and the encouragement of new 'knowledge' or 'learning networks'. The next section looks at the introduction of ICTs in manufacturing sectors in the context of industrial reorganisation over the past two decades.

3.6 Industrial organisation for the productive use of ICTs

The 'ICT paradigm' (see section 3.3) represents a major shift in industrial organisation. In the earlier period of mass production, enterprises survived and flourished by focusing on cost reduction as the key objective. This was achieved through the standardisation of final output, the use of special-purpose machinery, the development of work organisation, and tiered managerial structures built on a fine division of labour, and arms-length relationships with suppliers. The new forms of competition entail flexible customisation characterised by volatile and demanding final markets. Firms require the capability to compete not just on price, but also on a range of other features such as flexibility, quality, product variety, and time-to-market.

ICTs are playing an important role in meeting the multiple requirements of contemporary markets. Generally, they are implemented in ways that are flexible, highly fault-tolerant, and provide the capacity for meeting diverse and complex market requirements. The preceding section has emphasised the need for internal organisational learning to make the best use of the potential of these technologies. New principles of production flow have to be introduced that support operational flexibility, such as cellular plant layouts, the use of production-pulling techniques, and kanban control systems.[5] Quality at source has to be substituted for traditional end-of-line quality inspection and re-work. In addition, 'world class manufacturing' involves the endogenisation of incremental technical changes through processes of 'continuous improvement'.[6]

Further changes are needed in the firm's relationship within its 'productive chain' (with both suppliers and customers). The firm's inter-firm relationships become characterised by greater trust-intensity which substitutes for arms-length relationships. This involves long-term relationships with fewer suppliers, 'open-book' costing negotiations, and participation of many supply-chain firms in the technological innovation process, for example, simultaneous engineering. Extensive international experience has shown that these organisational techniques are a necessary precursor to the productive utilisation of ICTs not only in the automobile industry (Womack et al. 1990), but in a range of other sectors (Bessant 1991; Schonberger 1986). For example, it was only after these organisational techniques were adopted that Japanese automobile firms invested heavily in ICTs (Hoffman and Kaplinsky 1988).

These experiences are drawn from the industrialised countries. Are there obstacles which disadvantage developing countries in the adoption of these human resource-intensive organisational techniques?

In most developing countries production has occurred in relatively closed import-substituting markets, often in the context of significant supply-constraints. The pervasive shift towards more open trading conditions has left many enterprises ill-equipped to meet the needs of increasingly more demanding domestic customers, and especially external markets. A second factor that potentially disables the adoption of these organisational techniques in developing countries is the weakness of the supplier base, particularly for small and medium-sized enterprises. Supply-chain development is often a more daunting task. New forms of organisation (and indeed the productive use of ICTs) also require adequate physical infrastructures including the traditional roads and ports and the new 'information highways'. Finally, low levels of education in many developing countries may undermine the capacity to introduce the new forms of organisation (Jaikumar 1986).

The shift required in organisational structures and processes generally is larger in developing countries than in the industrially advanced countries. This suggests that developing countries are significantly disadvantaged in their ability to introduce the organisational techniques that are necessary in today's global markets and are essential precursors to the successful adoption of ICTs. There is insufficient evidence to make an overall assessment, but there is evidence that enterprises in a growing number of diverse developing countries are making successful use of new forms of organisation.

New forms of layout and production control, for example, have allowed a Zimbabwean enterprise to reduce its costs significantly (see Box 3.2). In India, changes in organisation on both the shop floor and especially in white collar work have allowed an electrical firm to slash its lead times (see Box 3.3). The same Indian enterprise has demonstrated its capacity to upgrade its supply chain in order to improve the overall efficiency of its productive cycle. Similar stories can be told for Brazil (Fleury and Humphrey 1992), the Dominican Republic and Mexico (Kaplinsky 1994), and for a range of other low-income countries.

These experiences of using new forms of organisation result in the emergence of what economists call a 'superior technique'. They provide the capacity not only to enhance quality and product variety, but also to reduce costs and meet the requirements of small markets more effectively. As firms in developing countries increasingly operate in open markets, it is likely that the introduction of such organisational techniques will become more widespread. It is unclear whether ICTs represent a 'superior technique' or whether they simply offer a new form of mechanisation in which (expensive) capital is substituted for (cheap) labour. If the latter is the case, this could be a reason for the slower diffusion of ICT-related changes in the manufacturing sectors in many developing countries than in the industrially advanced countries.

3.7 Skills for capability building

The availability of appropriate skills is central to the successful deployment of ICT-based innovations that enable organisational learning. Compared to earlier technological systems, such as steam power or electricity, ICTs are unique in that they affect every function within a firm as well as every industry in the economy (Freeman et al. 1995). Even in the poorest countries, the rate of diffusion of ICTs is increasing partly as a result of the rapid growth of international electronic networking. Against this background, ICTs may offer opportunities for 'catching up' by developing economies primarily as effective users of the new technologies and services. This depends on an increase in the capacity to learn new techniques (Cooper 1998 forthcoming). The catching-up process requires certain technological capabilities in order to absorb and make the best use of the revolutionary technology. One of the most important prerequisites for building technological capabilities is the accumulation of the skills needed to use ICTs.

If the necessary human resource base is present in developing countries, this can give them an initial entry into the global economy. Changing skills requirements are altering the pattern of trade between the industrialised and developing countries and opening up new opportunities for those countries that can offer the necessary expertise (see Box 3.4). It is becoming easier to locate certain information processing services and some 'service components' of manufacturing production such as inventory control in low-wage economies. As a result, a substantial part of routine services, for instance data

Box 3.2 - Applying Japanese techniques in Africa

Many of the new industrial organisation techniques have emerged from high-tech industries in Japan. But they can be adapted to more straightforward industrial applications, as demonstrated by results from a Zimbabwean firm producing agricultural carts. They made a number of changes in factory layout, introduced just-in-time production and total quality control, and involved the workforce in continuous improvement activities. The result was a 35 per cent reduction in costs, with higher quality and more reliable delivery.

	Before changes	*After changes*
Time taken to pass through factory	8 days	80 minutes
Distance travelled by work-in-progress	3.2 km	100 metres
Labour input per item	23 hours	13 hours
Overall reduction in production cost		35%

Source: Compiled from Kaplinsky (1994).

Box 3.3 - Understanding the market: Cutting lead times to meet customer needs

An Indian producer of low-tension electrical switch gear found that a gap in the market lay in meeting customers' needs rapidly. By changing its internal organisation and its links with its suppliers, it slashed its lead-time from 57 to 24 days, and substantially increased its market share.

Activity	1995	End 1996
	Lead time (days)	
Order processing	10	1
Manufacturing lead time	28	18
Waiting time in dispatch	7	1
Transport	12	4
Total	57	24

Source: Humphrey, et al. (1998 forthcoming).

Box 3.4 - Global knowledge

At a conference co-hosted by the World Bank and the Government of Canada with the governments of Switzerland and the United States, the UN Development Programme and other partners asked the question: *'How can developing countries, and particularly the world's poor, harness knowledge for development, participate in the global information economy, and gain access to the new tools for lifelong learning?' (Global Knowledge 1996).*

entry, is increasingly being re-located in developing countries such as India or the Philippines. More highly skilled jobs, such as computer programming, are also being relocated to these countries. It is not the absolute cost of labour that attracts transnational companies to locate their information processing work in developing countries, but the relative cheapness of the requisite skills.

The absorptive capacity based on appropriate technology related skills needs to be measured against both the demands of the international economy and the local environment where a skills base for using ICTs is even more important. Training geared predominantly to the needs of the global economy can lead to a massive 'brain drain', as can be seen from the experiences of India, South Africa, and the Mahgreb (Djeflat 1998 forthcoming; Kaplan 1996). It has been claimed, for example, that the cost of training computer programmers who have migrated from India to the United States has, to a large extent, counterbalanced the aid India received from the United States in the last decade (Pundit 1995).

The dramatic shifts in skills requirements in domestic and international markets have led to an adjustment lag, resulting in macro-economic and micro-level skills mismatches in developing countries. At the macro-economic level, the 'knowledge intensive' economy is experiencing rapid growth in information-intensive services and manufacturing and the borderlines between manufacturing and services activities are becoming blurred. For example, inputs of information-processing services have reached 70 per cent or more of the total production cost of automobiles. In this and other manufacturing sectors 'over three-quarters of the value of a typical "manufactured" product is already contributed by service activities such as design, sales and advertising' (The Economist 1996: 44). This clearly creates a major challenge for formal and informal education and training systems in developing countries.

At the micro-organisational level, the diffusion of ICTs is characterised by a transition to new types of work organisation that are giving rise to increasing reliance on 'lean management' and to outsourcing of activities. Traditional centralised manufacturing based on assembly line types of mass production are shifting to decentralised production modes based on networks of subcontractors. Changes in management philosophy are giving opportunities to the small and medium-sized enterprises that cater to the demands of national and internationally operating companies. However, the businesses that fare well under the new management organisational scenario are those which acquire the necessary business, commercial, and technological skills.

Capacity building to develop appropriate skills is a dynamic process. As technologies change at increasingly dramatic speeds, so do the skill requirements of people in businesses and in their everyday lives. Lifelong learning is becoming the essential prerequisite for lifelong employability and there is growing emphasis on multi-skilling and the ability to learn new skills (OECD 1992). Education and training systems and labour market institutions are core elements in overcoming skills mismatches and adjusting to the characteristics of knowledge production. The problems of structural adjustment are even greater for developing countries which lag far behind the advanced industrialised economies in their flexibility to cope with these challenges.

Women's training is a crucial aspect of skills availability in developing countries. Access to certain cognitive skills is becoming one of the main determinants of both productive efficiency and distributive justice. It is very important to ensure that the contribution which women can potentially make to emergent knowledge-intensive economies is fully mobilised. Therefore, the inadequacy of current training systems to meet the educational and vocational aspirations of women should be at the core of policy-oriented research in order to improve existing training for the benefit of women and their countries (Mitter 1993, 1995).

3.8 Alliances, partnerships, and trust

The skills base is central to building the competencies to manage the technological innovation process. The transformation of the skills base is especially visible in the management of very large-scale projects that are involved in constructing the national information infrastructures in developing countries. The available skills must be appropriate for handling complex products and systems integration in the telecommunication, computing, and software sectors. While the industrialised countries may be able to outsource service sector work to some developing countries, there is evidence that this will not necessarily be the case for the management and organisation of highly complex manufactured product systems (Mitter and Efendioglu 1998 forthcoming).

The production of complex products and systems (CoPS) includes high value products, capital goods, control systems, networks, and civil engineering projects for example, air traffic control systems, aircraft engines, bridges, chemical plants as well as electronic commerce systems, intelligent buildings, supercomputers, and telecommunication switching systems and mobile radio infrastructure (Miller et al. 1995; Hobday 1998 forthcoming). Large production projects in these sectors focus on systems design, engineering and integration skills. Some of the key characteristics are shown in Table 3.4.

Advanced ICT systems are essential to the coordination of CoPS projects as well as to the design of innovative products and systems. It may be that the skills required for managing and organising the production of CoPS will be retained in the industrialised countries because they are high value knowledge assets, while the skills more closely associated with back-office services and international capital flows migrate to some of the developing countries.

Questions about the whether developing countries should have the capability for producing ICTs in order to use them effectively in applications such as the design of complex products have been central to debates about the need for capital goods production capabilities in developing countries (Cooper 1998 forthcoming). Developing countries have answered these questions in different ways. However, if people are to be able to take advantage of the availability of national information infrastructures they will need the skills to manage and operate increasingly complex systems.

Table 3.4 - Complex products and systems, and product organisation

Product characteristics	Complex component interfaces Multi-functional High unit cost Product cycles last decades Many skill/knowledge inputs (Many) tailored components Upstream, capital goods Hierarchical/systemic
Production characteristics	Project/small batch System integration Scale-intensive, mass production not relevant
Innovation processes	User-producer driven Highly flexible, craft based Innovation and diffusion collapsed Innovation paths agreed *ex ante* among suppliers, users, etc. People embodied knowledge
Competitive strategies and innovation coordination	Focus on product design and development Organic Systems integration competencies Management of multi-firm alliances in temporary projects
Industrial coordination and evolution	Elaborate networks Project-based multi-firm alliances Temporary multi-firm alliances for innovation and production Long-term stability at integrator level
Market characteristics	Duopolistic structure Few large transactions Business to business Administered markets Internalised/politicised Heavily regulated/controlled Negotiated prices Partially contested (markets)

Source: Adapted from Hobday (1998 forthcoming)

One means of acquiring these skills is as a result of technology transfer which is increasingly regarded as desirable to parent companies and to recipient countries. Frequently manufacturing technology transfer involves operational technologies, maintenance, and inspection of technologies. Motivations for undertaking foreign direct investment range from wanting to take advantage of cheap labour, to business partners who invest because subcontracting a production system is important. A study of Japanese multinational parent companies that have expanded their activities by investing in East Asian countries has shown that the transfer of manufacturing technologies seems to improve with the length of operation in the host country. However the transfer of very sophisticated technology and skills depends to a greater extent on the ability of local management to exert pressure on the parent company, a high share of local workers, and the managerial status of local employees in the host country (Urata 1997).

Joint ventures and other types of alliances are potentially important means of building appropriate skills for using ICTs. Strategies based on competition are giving way to strategies that explicitly incorporate cooperation. Collaborative agreements are important sources of competitive strength and the importance of collaborative agreements is growing on a global scale. The promotion of cooperation by policy-makers in developing countries is crucial if they are to cope successfully with industrial and technological change in a turbulent international environment (Hillebrand 1996).

Joint ventures involving multinational companies are an increasingly common form of cooperative arrangement in industrialising economies (Freeman and Hagedoorn 1994). Government policy-makers often encourage joint ventures as a mechanism for transferring advanced technology and modern managerial practices to local firms. Despite their widespread occurrence, the management of joint ventures has proved to be problematic because multiple ownership increases the scope for potential conflicts between joint venture partners.[7] In addition, joint ventures may not meet parent company expectations. For example, the performance of nearly two-thirds of joint ventures in the developing countries examined in one study was considered to be unsatisfactory by the managers of multinational corporations (Beamish 1984). Joint ventures will not offer a particularly effective mechanism for technology transfer or a way of strengthening skills in developing countries unless their dynamics are better understood.

Empirical studies on the successful formation and operation of cooperative relationships highlight the crucial importance of intangible factors such as trust (Faulkner 1995; Schaan and Beamish 1988). Trust is a key factor in cooperative strategies (in contrast to competition) and involves mutual obligations (Buckley and Casson 1988; Thompson 1967). An explicit focus on trust, and concepts such as forbearance and commitment, is helpful in understanding the impact of different forms of business organisation and behaviour (see Box 3.5). It provides a basis for the formulation and implementation of development strategies by national governments, companies and other participants within and outside developing countries.

Box 3.5 - Trust and cooperative partnership strategies

> Over the last decade or so, interest in trust has increased dramatically as its crucial social and economic importance has become more apparent (Fukuyama 1995). In the context of partnerships, trust is a mechanism for reducing uncertainty and increasing the predictability of desired outcomes. Trust can be placed in individuals (personal trust) or in institutions (impersonal trust) and each of these consists of promissory, goodwill, and competence components (Granovetter 1985; Shapiro 1987).
>
> Promissory based trust is the degree of confidence with which a party can be relied upon to carry out a verbal or written promise (Rotter 1967). Goodwill based trust is the degree of confidence that a party can be relied upon to engage in actions which benefit the other party or refrain from actions which would disadvantage or damage the interests of the other party. This component of trust is related to the concept of forbearance, the situation where one party to a transaction will accept a time lag between fulfilling another partner's expectations and having their own expectations fulfilled in return. An essential aspect of trust is being open to the risk of parties reneging on a deal. Competence based trust is the degree of confidence with which a party can be relied upon to have the knowledge, skills, or expertise they claim or are believed to have (Sako 1992).
>
> Personal and impersonal trust are likely to develop in different ways. Personal trust emerges in networks in which individuals engage in complex bartering of favours to build up mutual obligations. Processes of personal trust require intensive social interaction starting with minor exchanges whereby actors test each other before moving to bigger transactions (Blau 1964; Butler 1983; Shapiro 1987). Impersonal trust develops in institutions involving well defined rules and is thus closely related to the processes of decision-making.

Trust can be examined as a central mediating variable between the *context* of the joint venture arrangement (the interdependence between the parties, competition and ambiguity) and the *outcome* or performance. The results of case studies of joint ventures in the United Kingdom and Malaysia in sectors including automobile components, textiles, and natural resource consultancy between private and public sector organisations, show that trust is extremely important (Butler and Gill 1996, 1997; Gill and Butler 1996).

- Partner choice and the success (or failure) of partnerships are crucially affected by trust between the parties and contextual factors. Key contextual factors are the perception of mutual benefits between the organisations and whether competition is endogenous or exogenous in the cooperative arrangement.
- Symbols of trust and the interpretation of trustworthy behaviour are affected by the culture of the organisations in the partnership. There are variations within firms of the same nationality arising from different historical experiences or developments. Ownership type is important since organisations from the public sector or NGOs have different cultures from those in the private sector.
- Personal relationships are at the core of trust between organisations. Although instability in joint ventures arises from changes in personnel and the environment, the joint venture form is better suited to the transfer of the tacit component of knowledge (Teece 1981; Millar et al. 1996).

In the ICT sector the outsourcing of software development has led to countries like India and China generating software code for firms in industrialised countries, in some cases, through joint ventures. Trust is important because customers in industrialised countries require credible suppliers. Mechanisms for enhancing trust are needed so that policies aimed at building this kind of tele-trade are successful.

In general, industrialisation strategies have focused on the macro-level aspects of technology transfer where the crucial choices are the transfer mechanisms (for example, licensing, joint venture, technical assistance), rather than on the inter-organisational dynamics and trust. Analysis of the latter micro-level issues is needed to understand the processes underlying the (un)successful transfer of knowledge, skill and ICT applications between organisations.

ICTs increase the technology-intensity of manufacturing and services because information-processing becomes more central to their production and use. Expenditure on technology for services is growing rapidly in the industrialised countries and a greater proportion of investment is being directed towards equipment rather than fixed plant and other physical assets (Miles et al. 1990; OECD 1993b). Services are users of ICTs and some are highly innovative in their use of new ICT system configurations and applications while others play a substantial role in helping to diffuse ICTs via marketing, training, and consultancy (Miles 1996).

The features of the new electronic services are affecting the organisation of the innovation process in the manufacturing and service sectors. Services present additional challenges for developing countries because the innovation process in services differs rather substantially from that in the manufacturing sectors and natural resource industries. The relationships between service suppliers and clients and the modes of service delivery are very important in the production and use of services. Innovation in services involves a learning process where firms use ICTs for more than the support of routine information processing applications. ICT-based services, such as advanced management information systems, become strategic

Table 3.5 - Factors in ICT adoption success and failure

Core factors	Symptoms	Consequences
Institutional weaknesses	Insufficient planning	Inadequately designed systems
	Unclear objectives	Cost over-runs
Human resources	Shortage of qualified personnel	Insufficient support
	Lack of professional training	Isolation from sources of technology
Funding arrangements	Underestimated project costs	Unfinished projects
	Lack of recurring expenditure	Higher costs for software development and repairs
Local environment	Lack of vendor representation	Lack of professional to solve technical problems
	Lack of back-up equipment and spares	Implementation problems and delays
Technology and information changes	Limited hardware and software availability	Incompatible hardware-software
	Inappropriate software	Over-reliance on customised applications

Source: Adapted from Miles (1996).

assets that underpin other activities in the manufacturing process and in public and commercial service delivery. The recombination of these knowledge assets with intangible, tacit knowledge helps firms to compete in global markets.

Table 3.5 shows that the institutional environment in the public and private sectors, the skills base, the availability of financing, and the technological capabilities in the local environment, together with the rate of innovation in ICTs, are contributing factors to the success or failure of the adoption of ICT-based services.

The evidence on the factors contributing to the success or failure of the adoption of ICTs and services by firms in developing countries is very limited. However, case studies of successful and unsuccessful applications suggest that: large firms often act as drivers in the introduction of ICTs; financial service firms are the prominent early adopters; competition in telecommunication service supply has a positive influence on the rate of diffusion of ICTs; a modern telecommunication infrastructure is important for the successful introduction of ICT-based services; network externalities are important for the rate of expansion of the use of ICTs; product champions have a decisive impact on speeding the introduction of ICTs in firms; and innovative firms or individuals are important in the diffusion of new technologies (Miles 1996).

Systematic evidence on how these factors interact with the social and economic conditions in developing countries, and especially the least developed countries, is needed if these countries are to develop effective strategies for improving their use of ICTs in all sectors of the economy. The following section provides a case study of the factors influencing the management of technological innovation in the ICT sector in China. This case study illustrates how this country has developed strategies to build capabilities for using ICTs to strengthen the economy.

3.9 Managing technological innovations in China

The production and use of ICTs in China are characterised by rapid increases in the volume and range of both domestic and imported ICT products. This rapid increase on the supply side has been triggered by fast-expanding domestic demand from industrial and private users. Table 3.6 shows that the increase in the quantity of ICT products consumed over the past 15 years has been phenomenal.

Table 3.6 - Consumption of ICT products in China, 1980-1995 (in '000s)

Consumption	1980	1986	1990	1993	1995
Total no. of computers	2.0	190		1,014	1,600
- of which domestically produced				93	800
Communications:					
No. of office program-controlled exchange lines			13,000	35,670	70,000
No. of mobile phones			18	421	3,500
No. of pagers					25,000
No. of telephones					54,000
Internet (no. of users)				6	50

Source: Data compiled from various issues of *Computer World* (1997) and *China Computer Daily* (1997) (Chinese).

Rapidly increasing demand for high-technology products in a developing country like China has substantial implications for the management of the innovation process. For example, escalating demand is raising questions about the evolutionary path of growth, the means of technology acquisition and the diffusion processes within Chinese organisations.

The western literature on China has been concerned primarily with issues such as the process of industrialisation in developing countries (Baark 1986), how to do business with China (Adler et al. 1992), and cross-cultural issues involved in international technology transfer (Minkes 1995; Tsang 1995). Despite their contributions to a better general understanding of China-related issues, there is a very great need for interdisciplinary analyses that grasp the extremely diverse nature of China's economic, technological, industrial, and market development. Concepts such as sectoral or regional systems of innovation are useful. However, the application of these concepts needs to reflect the diversity and radical nature of China's economic and technological development. The concepts must be adapted to reflect the different experiences of China as compared to countries like the Republic of Korea or Taiwan (Pr. China).

3.9.1 The evolutionary path of rapid growth in China

Several growth models have been used to explain the evolution of ICTs in the western industrialised countries including the 'three-era model' where ICT applications evolve from data-processing in the 1960s, to information systems in the 1970s, and to strategic information systems in the 1990s (Ward et al. 1990). In the 'three phase model', the hardware constraints of the 1960s are followed by software constraints in the 1980s, and user relationship constraints in the 1990s (Friedman 1990).

In China, the development of ICTs differs from the evolutionary paths suggested by these two models. Although China made its first computer in 1958, only a few years later than the western industrialised countries, the production and use of computers were restricted to research in the field of military technologies. The production of the first computers drew upon China's large resource endowment in basic science. The first civil ICT applications were for word-processing and technical calculation and they were used in national administrative departments and in a large vehicle manufacturers.

In the 1980s China began to pursue a new ICT policy – 'Import, Digest, Develop, and Create'. ICTs were identified as a key high-technology in China's '863' plan. In 1993, the State Council set up an organisation called the Joint Meeting of National Economy Informatization to promote further development and use of ICTs.

With the opening of the country's economy and its rapid growth, the orientation of scientific and technological development has shifted dramatically from 'defence-push' to 'market-pull'. The disadvantages of the old strategy with its exclusive emphasis on basic science and military technologies have become obvious. These include the absence of technologies that can be applied as a result of the slow speed of early technology development, low cost effectiveness, and weak understanding of the market. The result has been a heavy reliance on imported goods and technologies, poor quality domestic products, and low success rates in efforts to bring superior technologies to the market. For instance, of total PC sales of 1,600,000 units in 1996, and only 50 per cent were produced by domestic companies, such as Great Wall and Legend. Most of these were sold to home users who are much less quality-conscious than industrial users.

A distinctive feature of the evolution of China's ICT capabilities since economic reform in the 1980s is the overlap of the phases of the growth models developed in industrialised countries. For instance, although Chinese organisations have yet to master the use of information management systems, the Internet has entered the market and use of it is increasing.

3.9.2 Technology acquisition by Chinese businesses

The development paths of China's technologies, such as ICTs, are heavily conditioned by past historical and political situations. For more than 40 years, the strategy of the Chinese government in technology development was one of technological self-reliance rather than imitative learning, as in the case of countries and territories like the Republic of Korea and Taiwan (Pr. China), or technological dependence, as in the case of Hong Kong and Singapore (Kim and Ro 1995). Technology self-reliance depended heavily on indigenous development as the typical acquisition mode for new technology with a strong focus on the accumulation of in-house technical capability. Consequently, China is behind other East Asian countries in most fields of commercial goods manufacturing and application technologies, although it has substantial technological capability in military satellite and microwave transmission systems (He 1997).

China has been one of the largest importers of technology in the world since the 1980s. Among the various channels for absorbing foreign technology, the Chinese government has a strong preference for joint ventures (Tsang 1995). During the initial years of economic reform, China maintained tight control over inward foreign investment. Laws governing wholly foreign-owned enterprises were promulgated only in 1986, eight years after the start of reform. At that time, the Chinese government already had abundant experience in handling foreign investment and so was more confident about its ability to direct foreign-owned subsidiaries. Other means of technology transfer, such as turnkey projects, licensing, etc., have been played down. First, importing a complete production unit is very costly and often includes components that can be purchased domestically at lower cost. Second, these approaches did not yield the know-how expected by the Chinese and failed to spread the technology. There is substantial evidence to show that licensing in isolation is efficient for transferring only older, codifiable knowledge (Hennart 1988, 1989). As China's purpose in importing technology has been to develop its export capability and to compete in international markets, interest has focused more on complex technology at the cutting edge than on older generations of technology. When knowledge is tacit, close interaction between the transferor and the transferee is required and, as a result, licensing alone is insufficient.

Joint ventures have been the primary means of technology transfer in China for four reasons: the Chinese partner has a say in the management of a joint venture; the commitment of the foreign investor to make the project a success is secured; the transfer of sophisticated technology requires close interaction; and the transfer of much-needed managerial know-how is included.

There has been a rapid increase in the number of joint ventures since the start of the reform. For example, in 1996 a Mitsubishi-Stone joint venture was initiated in Beijing with total investment of US$ 2 billion and a capacity of 20,000 8-inch chips per month. Another joint venture company, Saiyifa, was set up in Shenzhen with a total investment of US$ 7.7 million. However, the technological element of these joint ventures is low since most of the equipment needed for the production of integrated circuits and chips, etc., is imported, and the main activities of these joint ventures are concerned with the final stages of production.

There are two categories of joint venture, Original Equipment Manufacturers (OEM) and production of goods predominantly for domestic consumption (Hobday 1995). The extent to which Chinese partners in joint ventures in each of these categories can build up their own technological and managerial capabilities through cumulative learning is an important issue for China.

3.9.3 The diffusion of ICTs within Chinese organisations

Although the Government has been trying hard to push Chinese organisations to use ICTs, the results have not been promising. Three factors need to be considered to understand this: culture, technical skills, and the management structure in Chinese organisations. First, there is a potential contradiction between the implementation of ICTs and the organisational culture in China. The 'power-distance dimension' describes the extent to which a country accepts the fact that power is distributed unequally (Hofstede 1980). Chinese organisations are modelled on the family and are operated under a highly unequal distribution of power. The application of ICTs has two kinds of impacts. The installation of information systems increases the degree of transparency and information sharing across the organisation; and the use of computers tends to marginalise older, more senior people in the organisation (Zhao and Grimshaw 1991). This helps to explain the reluctance of some Chinese managers to introduce computers and information systems.

The second factor is concerned with the lack of technically skilled workers. The labour market in China has two tiers with an over-supply of unskilled workers and a corresponding shortage of professionals and managers (Tsang 1995). The huge population accounts for the excess of unskilled workers while two main factors are responsible for the shortage of professionals and managers: higher education cannot keep pace with the country's rapid economic development; and the destruction of education which was brought about by the Cultural Revolution (1966-76). During those ten years, intellectuals were sent to farms to undertake manual labour and the universities were closed down. This shortage of technical personnel is detrimental to technology transfer and diffusion. Organisations often purchase the latest computers and information systems as their first ICT investment because of a strong desire to catch up. However, neither the skills nor the organisational structures are adequate to handle the new technology. On the other hand, technical personnel in China are renowned for their quality. A survey of joint ventures located in Shanghai found that Chinese engineers and technicians were praised by both Japanese and US managers as hard-working and creative (Stavis and Gang 1988). Also, salaries are much lower than for their counterparts in the industrialised and newly industrialising countries, and this is regarded as an advantage for establishing high-technology industries such as ICTs.

The third factor concerns the organisational structures and the lack of managerial skills. Under the previous, centrally-planned economic system, a Chinese enterprise was a production unit inside the vast planning system. Each year, it was assigned a production output quota, and all its products were sold to the state at a predetermined price. Any profit was handed over to the state and any loss incurred was automatically absorbed by the state. Investment decisions could not be made independently, and the enterprise had little say in personnel matters, including salary scales, recruitment, dismissal, etc. Such modern management skills as marketing, corporate planning, finance, and human resource management were alien to Chinese managers until the mid-1980s, when more authority and responsibility were given to them under the 'manager responsibility system'. Since then, Chinese managers have been undergoing a period of adjustment and re-training. However, this is a slow and painful process, and the lack of competent and qualified managers in Chinese organisations remains one of the biggest obstacles to promoting and enabling the diffusion of ICTs at firm level. As a result, ICT applications are generally restricted to data-processing, calculation, accounting, etc., despite some successes in other areas such as the application of computer-integrated-manufacturing systems (CIMs) (Wu 1995).

3.9.4 Building capabilities in China

The demand for ICTs in consumer and industrial markets has expanded rapidly in China but the production capabilities of domestic producers are being marginalised by foreign producers and as a result of joint ventures. The volume of production is considerable but this is mainly for home use and is of relatively low quality. Many domestic producers are spin-offs from research institutes, originally with the aim of commercialising their research results. So far their performance has been limited by lack of experience in market environments.

In the longer term, domestic producers will continue their struggle to upgrade the quality of their products, to introduce new models, and compete head-on with foreign producers and joint ventures in both domestic and global markets. The likelihood of success depends on their ability to transform basic technologies into commercial products, to form strategic alliances with other East Asian countries, such as the Republic of Korea, to obtain application technologies, and to master modern management techniques through a process of learning-by-doing. In the meantime, the majority of the current joint ventures are for OEM production. They remain the primary focus for technology transfer and have assisted Chinese organisations in the acquisition of managerial skills.

The use of ICTs in Chinese organisations is characterised by a mismatch between the highly advanced technologies that are often adopted and the low level of managerial and technical skills within the organisations. Diffusion of ICTs has been limited to a relatively narrow range of sectors and functions, and the development of ICT systems in China is extremely uneven throughout industrial sectors and regions. Most of the organisations which have intensive investments in ICTs are in the aeronautics, telecommunication, chemicals, and manufacturing sectors. The ICT intensity is much lower in the agriculture, transportation and health-care sectors. There is also a considerable gap in ICT intensity between big cities like Beijing, Shanghai, and Guangzhou and small towns and villages, and between the developed Southeast regions and under-developed Northwest regions. The problem of how to reduce these gaps remains a big challenge for the country.

This challenge is being taken up by the State Science and Technology Commission by their appointment of an international team to undertake a comprehensive review of China's experience over the last decade in the reform of its science and technology system. The team concluded that 'there is not an explicit policy in China for international collaboration in science and technology that fully embraces the implications of today's realities in technological development' (Oldham 1997: 6) and recommended that more emphasis be placed on international collaboration in science and technology in order for China to learn about other international experiences.

3.10 Conclusion - Technology choices, selection, and capability building

The scientific and technological innovation process always brings challenges for policy-makers. Decisions must be made about whether or not new technologies should be adopted. The future of 'legacy' technologies when a new ICT good or service emerges needs to be considered and the appropriate balance between the old and the new options is subtle. There are often limitations on the financial and knowledge resources available, that help in making these choices. A decision to adopt a particular technology can limit the 'degrees of freedom' of decision-makers and users in the future.

The way in which Brazil chose to adopt earth station technology for its satellite communication system in the 1960s illustrates the complexity of the technological assessment process that is needed to choose between competing ICTs and to ensure that management and other skills are built up in order to use the new system effectively (Ferreira Silva 1996). In the case of Brazilian satellite technology, the existing technical options were the continued provision of international telecommunication services using high frequency (HF) radio or submarine cables. Both these technologies had limitations. Telecommunication circuits were limited in quantity and the quality of transmission was relatively poor. New satellite communication technologies appeared to provide a solution to many of the technical constraints.

The process of decision-making leading to investment in satellite communication technology involved the recognition by policy-makers that the selection of a new technical system should be based upon a comparison of the technical features of available alternatives, and that it needed to take account of constraints on decisions originating in the domestic and international environment. In the 1960s there was a shortage of financial resources, very limited technical knowledge, and an almost complete absence of technological and institutional organisational capabilities relevant to the development of satellite communication systems. A detailed assessment of the technical and economic features of competing systems, the political issues, and the required competency base, led to the successful adoption and development of a satellite communication system in Brazil.

This Brazilian case illustrates the importance of techno-economic factors relating to the scale of investment, the level of profitability, the learning processes, the market competition expected, the speed of technical innovation, and the productivity gains. Political factors were important including the willingness of countries leading in the production of the new technology to share technological knowledge with a developing country. It was also necessary to participate in, and comply with, an emerging international regulatory regime which was affecting the design of satellite systems and the technology transfer schemes available to Brazilian firms. The technology selection process involved a high degree of uncertainty and unpredictability, but the technology assessment process gave rise to opportunities for learning-by-using and learning-by-doing.

Developing countries need to acquire capabilities for a wide range of technology assessment practices in order to encourage effective technological learning by firms. As the global economy is transformed and the locus of power and the capabilities for action are re-distributed, there is a need for associated changes in management practices, new forms of organisational learning, and to develop effective partnerships that can lead to the accumulation of both technological and social capabilities.

The generic policy remedies that are available to developing countries to improve the links between technological innovation and development priorities include incentives introduced through macro-economic policy measures, increased role of competition in domestic markets, and measures to foster the competitiveness of domestic firms in foreign markets. Policies addressed to the skills base in management, technical, production engineering, design and development, scientific research, and organisational and marketing fields are also important. Policies which generate financial resources and focus directly on building technological capabilities can be combined with those which focus specifically on building up information on the range of technological options. Access to collaborating researchers who are producing new knowledge, standards, metrics and testing advances, support for basic research, and access to external sources of technology are important, but access to knowledge (with or without ICTs) is not sufficient. The remedies for weaknesses in these areas put a high premium on clearly identifying learning opportunities, strengthening knowledge in key areas, and selectively supporting priority sectors (Lall 1995; Reddy 1996).

Although production capabilities are important for creating technological capabilities, they are not the only pathway to effective use of ICT hardware. It also is not yet clear whether developing countries need to be able to produce software in order to use it effectively. It does appear that developing countries need to be able to provide ICT application support services and this implies the need to ensure that the population has a range of skills that are in some cases very similar to those needed for the development of software (Cooper 1998 forthcoming). Informal learning processes in firms will remain vitally important as this chapter has shown. Chapter 4 turns to the institutions of formal education and their use of ICTs to enable new forms of learning.

Notes

1 *For example, a decision to establish a new degree programme in one developing country might involve four partners; one providing the bulk of the teaching; a second providing experimental sites for thesis work; a third (in the industrialised world) assisting with course design, providing some teaching, and accrediting the whole programme; and a fourth providing pump-priming funds.*

2 *See Lundvall and Johnson (1994); Lundvall (1996a, 1996b); Foray and Lundvall (1996) and similar perspectives such as Drucker (1993).*

3 *The concept of tacit knowledge was developed by Michael Polanyi in the late 1950s and early 1960s, see Polanyi (1966). For a review of recent discussions on tacit (heuristic, subjective, internalised) knowledge as compared to knowledge that can be transmitted using a formal, systematic language (codified knowledge), see Senker (1995). Note that there is debate about the distinctions between the two types of knowledge.*

4 *The problems experienced by IBM, whom one might have expected to master the use of advanced business information systems, illustrate the point.*

5 *The 'kanban' control system refers to just-in-time production systems and organisational techniques developed by Japanese companies which originally were making very little use of ICTs. Such systems ensure that work in progress is pulled rather than pushed through the plant.*

6 *'Endogenisation' refers to the process of creating and embedding local capacities within domestic firms through processes of continuous improvement and learning.*

7 *Killing (1983) recommends forming joint ventures in which one partner has dominant equity control, but the understanding of joint ventures is incomplete (Parkhe 1993).*