ICT Policies and Educational Transformation

A UNESCO Publication

EDITED BY ROBERT B. KOZMA, PH.D. ¹

CHAPTER 1

The Technological, Economic, and Social Contexts for Educational ICT Policy

ROBERT B. KOZMA, PH.D.

Introduction

The dissemination and use of information and communications technologies (ICT) in schools has come to be seen by education policy-makers as a significant opportunity. They are attracted to the prospect that ICT can improve student achievement, improve access to schooling, increase efficiencies and reduce costs, enhance students’ ability to learn and promote their lifelong learning, and prepare them for a globally competitive workforce. As the power and capability of computers have increased, as they have become interconnected in a worldwide web of information and resources, as they provide a conduit for participation and interaction with other people, as they have become linked to other devices, and as their costs have come down, policy-makers, particularly those in developing countries, have come to see ICT as a viable, and even dramatic, way of responding to the multiple challenges that they face.

Once policy-makers consider making significant investments in ICT, a host of questions emerge: How many computers are needed in a school? Where should they be located? How should the network architecture be structured? How should the computers be distributed equitably? What additional resources are needed to support their use? What kind of training do teachers need to take advantage of

these resources? How can they use them in their teaching? Are these uses effective? Are these even the right questions?

The position taken in this book is that while these questions represent important implementation issues, they are not the questions that should frame ICT policy. ICT can have a greater impact when the policies and programmes designed to implement them are crafted in the broader context of social and economic goals and when they are implemented in support of coordinated change of all the components of the education system, aligned to a vision of economic development and social progress— that is, when ICT policies and programmes support educational transformation.

The world is experiencing a major shift from an economy and society based on mass production to one based on knowledge creation. This shift has significant implications for the development of human resources and for changes in all of the components of the education system, not just the use of ICT. Within this context, the driving questions that frame ICT policy are: What is the nation’s vision of how education can support economic and social progress, and what are the potential roles of ICT in supporting educational transform aligned to these goals?

The book examines the range of educational experiences, practices, and issues and presents them in a way that can be used by decision makers crafting ICT policy in education. However, with this chapter, the book begins by considering the broader technological, economic, and social trends that have been sweeping the globe and moving toward an information economy and knowledge society. It examines the dramatic increase in capabilities and use of ICT and their related social and economic impact—positive and negative—in both developed and less developed nations. The chapter then examines research on the impact of ICT on education. So far, ICT have had much less impact on education systems than they have had on the economy or society, as a whole, in large part because the education system, in general, is now out of sync with ICT-based economic and social developments. The chapter ends with a call to transform education in a way that will advance the social and economic development goals of a country.

The second chapter goes on to consider the implications of these global technological, social, and economic trends for educational transformation and the use of ICT to support these changes. Building on earlier work (UNESCO, 2002; Kozma, 2005; UNESCO, 2008; Kozma, in press), the chapter presents a framework—the Knowledge Ladder—that provides educational decision-makers with a way of thinking about policies that integrate ICT plans and programmes with other components of the educational system (such as curriculum, pedagogy, teacher training, assessment, and school organization) and with national policies, in a way that addresses the broader social and economic goals of the country and moves toward an information economy and knowledge society. Finally, the chapter reviews the policy development process and provides decision-makers with recommendations and suggestions for how they can coordinate ICT with the broader development goals and education reform agenda.

Five subsequent chapters review the policies, programmes, and experiences in range of regional and developmental settings—Jordan, Namibia, Rwanda, Singapore, and Uruguay. The final chapter draws on issues introduced in the early chapters, analyses the findings across case studies, and considers their implications for educational policy, change, and transformation.

This publication is an offering of the UNESCO Division of Education Strategies and Capacity-Building. The education programmes of the United Nations and UNESCO address many of the diverse purposes and goals that confront education policy-makers. For example, the Millennium Development Goals (MDG), Education for All (EFA), the UN Literacy Decade (UNLD), and the Decade of Education for Sustainable
Development (DESD) all aim to reduce poverty and improve health and the quality of life and view education as an important contribution to these goals (UNESCO, 2005a). All of these aim to increase the equality of women and men and advance the human rights of all, particularly minorities. All are based on the belief that education is a key to development and a way of enabling people to fulfill their potential and take increasing control over decisions that affect them. The EFA and DESD place emphasis on the quality of learning. UNLD and EFA both place an emphasis on literacy as central to basic education and future learning. Beyond a high-quality basic education, the UNESCO International Commission on Education for the 21st Century (Delors, et al., 1999) contends that learning throughout life and participation in the learning society are essential for meeting the challenges of a rapidly changing world. Furthermore, ICT holds the unique promise of providing equal and universal access to knowledge in support of sustainable development (UNESCO, 2005b). Within this context, UNESCO has also produced a number of resources for policy-makers considering the use of ICT in education, such as ICT in Education (UNESCO, 2002), the ICT in Education Toolkit2 and the ICT Competency Standards for Teachers (UNESCO, 2008). UNESCO has also produced a world report entitled Towards Knowledge Societies which recognizes that ICT have the potential to enable many individuals, firms, communities, in all regions of the planet, to address economic and social challenges with greater efficiency and imagination (UNESCO, 2005b). This book complements and builds on these and is yet another resource for education decision-makers to help them craft policies and programmes that address their educational goals and priorities and advance social and economic development.

**Historic Development of ICT and Recent Trends**

Many of the momentous economic and social changes that have been experienced in the late twentieth and early twenty-first centuries have been facilitated by or are directly due to a dramatic increase in the capabilities and availability of information and communications technologies. The remarkable uptake of ICT has not only affected the technology and telecommunications sectors but rippled through nearly every aspect of the economy and society in many countries. How is it that this technology could have such a broad impact on the world?

**The Dramatic Increase in the Power of ICT**

First, the increased impact of ICT is due to a dramatic increase in its power. ICT cover a broad range of technologies. While commonly associated with computers, the term also includes other informational media, such as handheld devices, television, radio and even print. To these information technologies can be added communications technologies, such as telephones and networks. While this definition hardly leaves anything out, the power of the term comes from the convergence of the ever-increasing information processing capabilities of computers and the information exchange capabilities of networks. It is the combined processing and networking power of contemporary ICT that has launched a global socio-economic paradigm shift when other, earlier technologies like radio and television did not.

Initially, the processing capabilities of computers were very modest, their applications limited, and they were accessible to very few. The Electronic Numerical Integrator And Computer (ENIAC) is considered the first general purpose, programmable electronic computer and it was developed in 1946 at the

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2 ICT in Education Toolkit, UNESCO Bangkok, [www.ictinedtoolkit.org](http://www.ictinedtoolkit.org)
University of Pennsylvania for the US Army to compute artillery firing tables. In 1951, the Sperry Rand UNIVAC I was introduced as the first commercially produced computer at a price of about US$ 1 million. It used 5,600 vacuum tubes, weighed 29,000 pounds, occupied 3.5 m² of floor space, and performed 1,900 operations a second. A total of 46 were eventually built and sold to government agencies and large corporations. It was made famous in 1952 by allowing the early prediction of who would win the US Presidential election.

The introduction of transistors to replace vacuum tubes in the mid-1950s dramatically reduced the size and cost of computers, increased their performance, and created a technological revolution. Current laptop computers typically weigh less than 3 pounds, performs more than 60 billion instructions a second, cost less than $600, and the size is determined by how large a screen is desired. Handheld computers are even smaller than laptops and, although less powerful, are more powerful than the earlier, much larger desktop computers. On the cost side, the One Laptop Per Child XO machine and low-cost computers from other companies cost about $200, some less. Now a school child in developed countries typically has access to more computing power than the astronauts did when they landed on the Moon. The dramatic increase in power from 1,900 to many billions of operations per second and the corresponding drop in price from $1,000,000 to $600 or less and the reduction in size and weight are all a demonstration of “Moore’s Law,” which states that the number of transistors that fit on a computer chip double every two year. The law is expected to hold at least through 2015 and as the power of computers continues to increase it will continue to change the way people work, play, learn, and live around the world.

From an informational perspective, it is the processing capability of computers that gives them—and us—the power to change our lives. This processing capability makes it possible to use, change, or transform information in a way that is unique, compared to previous information technologies, such as print, radio and television, which merely distribute or broadcast information in one form or another (Kozma, 1991). The computer’s capability to transform information depends on the programs that are used with it. Appropriately written programs can perform mathematic, logical or graphical operations on a range of input. Early programs could take numerals as input, run calculations, and present the output as a set of tables. Or a user could enter text, rearrange it on a page, and print it out in various formats. The power of these early spreadsheets and word processors was sufficient to launch a dramatic uptake of computers in businesses in the 1980s.

As the power of computers increased, programs could be written that generated graphical output, simple diagrams at first but ultimately more sophisticated, realistic animations. Consequently, numeric, text, and other forms of input, such as joy sticks and styluses, could be used to control dynamic simulations. These faster, more powerful computers could also process sound and video so that information in these forms could be presented or created in response to user interests and needs. Consequently, users could manipulate or produce, as well as consume, multimedia content. The convergence of computers and multimedia significantly increased the use of the increasingly small computers for both home and educational purposes and, again, the uptake increased.

The second reason for the impact of ICT is their increased availability. As the capabilities of computers increased exponentially, their sales rose exponentially as well. In 1977, 48 thousand personal computers

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3 http://archives.cnn.com/2001/TECH/industry/06/14/computing.anniversary/
4 http://www.olpcnews.com/sales_talk/price/olpc_uruguay_205_dollars_laptop.html
were shipped. In 2001, 125 million were shipped. By 2008, the number of personal computers in use worldwide was 1 billion. This is an astounding number, particularly given that in 1943, Thomas Watson, Chairman of IBM at the time, predicted that the total market for computers worldwide was, perhaps, five.

**Telephones**

Communications technology, the other component of ICT, has a longer modern history than do computers. The telephone was invented in the late nineteenth century and came into common use in developed countries during the early twentieth century. Initial sales of telephones were poor, as there were very few others to call. But when sales took off, the growth was again exponential. Bell Telephone began selling phones in 1877. A year-and-a-half later, only 778 phones were in use. But by 1900, there were 5 million telephones in the USA. In 1979, the mobile cellular phone was introduced, which dramatically increased the range and flexibility of use of the telephone. By 2006, there were a total 4 billion telephone subscribers worldwide, 1.27 billion on a fixed line and 2.68 billion mobile subscribers.

**The internet and World Wide Web**

The convergence of computers and communication came relatively early in the development of computers. As soon as the technology enabled computers to connect with phones, developers began to think of ways that one user could communicate with others. Email was devised in 1961, prior to the development of personal computers, to allow multiple users who dialed into a large, mainframe computer from a remote teletype terminal to store and exchange information with other users of the same computer. This along with bulletin boards and newsgroups allowed hundreds—or even thousands—of users within a company or university to communicate and share information with others. Later, protocols were developed that allowed computers to connect and pass information from a user of one computer to users of another computer. These applications were early precursors to the Internet and the World Wide Web. In 1968, Douglas Englebart, a scientist at Stanford Research Institute, demonstrated the use of experimental technologies, such as the mouse, hypertext, and shared screen collaboration that would become standard features in future computer applications. The first two nodes for what was to become the Internet were established in 1969. By 1990, Englebart’s vision of a system for exchanging cross-linked, hypertext documents was established among scientists at a research laboratory in Switzerland. This would turn into the World Wide Web (or “the Web”), a system for posting and sharing multimedia documents with users around the world. As mobile phones became “smart”, acquiring some of the power of computers, as computers became wirelessly connected to the Internet and other multimedia devices, and as data rates of networks increased, access to and use of the Web increased dramatically. As of April 2010, the Web consisted of over 118 million websites and at least 20 billion pages. Not only does this network of devices allow people to produce, access, exchange, and share multimedia content and applications, it connects people to each other,

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7 Cited in the President’s Committee of Advisors on Science and Technology (2000), p. 3.

8 [http://www.ideafinder.com/history/inventions/telephone.htm](http://www.ideafinder.com/history/inventions/telephone.htm)


synchronously and asynchronously. This capability allows people at distributed locations to communicate and collaborate with each other, while taking advantage of a rich, multimedia, body of
digital content and has spawned a global network of social connections, communications, and
information sharing, often referred to as the knowledge society. UNESCO recognizes that ICT have
created new conditions for the emergence of knowledge societies. For UNESCO, knowledge societies
have the capability to identify, produce, process, transform, disseminate and use information to build
and apply knowledge for human development and suggest that the knowledge societies are a source of
development for all, especially the least developed countries. For this reason, UNESCO calls for inclusive
knowledge societies (UNESCO, 2005b). Part of this call is in recognition also of the uneven access to ICT
around the world.

The Distribution of ICT around the World

The information processing and connectivity of ICT can enable and enrich people’s lives only if they have
access to it. While the growth of ICT has been exponential, it has not been evenly distributed within
societies or around the world. An examination of data from the World Bank on the use of ICT across a
select group of countries shows significant regional and national differences (See Table 1).

The penetration of computers in high-income countries is quite high (67 computers per 100 people, as
of 2007) but very low in Eastern European and Central Asian countries (11 per 100), Latin American
countries (11 per 100), East Asian and Pacific countries (6 per 100), and Middle Eastern and North
African countries (6 per 100). They are particularly low for South Asian (3 per 100) and Sub-Saharan
African countries (2 per 100). Differences are even greater for Internet access. While Internet
penetration is still rather modest even in high income countries (26 per 100), it is very low in other
regions: Eastern European and Central Asian (14 per 100), East Asian and Pacific (9 per 100), Latin
America (4 per 100), Middle East and North Africa (2 per 100), South Asian (1 per 100) and Sub-Saharan
Africa (1 per 100).

Table 1. Information and Communication Technologies Indicators for Select Countries
(Source: World Bank, 2007\textsuperscript{13})

<table>
<thead>
<tr>
<th>Country</th>
<th>Population (Millions)</th>
<th>Economic Category \textsuperscript{14}</th>
<th>Per Cap GNI\textsuperscript{15}</th>
<th>% Households with TVs</th>
<th>Telephone Lines per 100</th>
<th>Mobile Subscribers per 100</th>
<th>Personal Computers per 100</th>
<th>Internet Subscribers per 100</th>
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<td>50</td>
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<td>65</td>
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\textsuperscript{14} H, high; UM, upper middle; LM, lower middle; L low, based on Gross National Income per capita.

\textsuperscript{15} Gross National Income: GNI is the sum of value added by all resident producers plus any product taxes (less
subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees
and property income) from abroad.
<table>
<thead>
<tr>
<th></th>
<th>82</th>
<th>H</th>
<th>38,990</th>
<th>94</th>
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Television

The penetration of television (TV), a more mature technology, is more even across countries. High-income, Eastern European and Central Asian, Middle Eastern and North African, and Latin American countries all have more than 80% of their households with TV. Even South Asian countries have a 42% penetration rate. However, as a group Sub-Saharan African countries have only an 18% household penetration rate of television.

Mobile phones

Telephones provide an interesting example of how countries can sometimes skip over technologies. The newer mobile telephones have exceeded the penetration of traditional land lines in most countries. In high-income countries, there are 100 mobile subscribes per 100 people, while there are only 50 land lines per 100. The difference is more pronounced in developing countries, where the growth of land lines was slow. For example, in South Asia there are 3 land lines per 100 but 23 mobile subscriptions. And in Sub-Saharan Africa there are only 2 land lines and 23 mobile phone subscriptions per 100. Admittedly, the mobile phones in developing countries are not likely to be high-end smart phones that provide access to media-­content on the Web, but mobile technology represents a significant opening for ICT advancement in developing countries.

Rates of hardware and connectivity penetration are not the only difference between developed and developing countries. There are significant differences in content available on the Web. A 2002 survey of 2,024 million Web pages determined that by far the most content was in English: 56.4%; next were pages in German (7.7%), French (5.6%), and Japanese (4.9%)17. Very little content is available in languages indigenous to developing countries.

Differences in access to computers and the Internet extend to groups within (and across) national boundaries that include those based on income, education, minority status, age, and gender and these differences limit the ability of these groups to participate in and benefit from technology-based economic development (Sciadas, 2007). For example, in a review of studies conducted in the USA, Warschauer and Matuchniak (2010) found significant gaps in home access to digital media, as well as inequalities in technology usage and outcomes between a number of groups. A study by the Pew Internet and American Life Project shows the following demographics using the Internet and email: 90% of those between the ages of 18 and 29, 91% of all college graduates, and 95% of those making $75,000 or more. This compares with only 59% of Black Americans, 53% of those making $30,000 or less, 44% of those with no high school degree, 35% of those 65 or older, and 32% of Spanish-dominant Hispanics who use these technologies.18 In many countries of the Organisation for Economic Cooperation and Development (OECD) there is a gap between women and men in their access to computers that ranges from about 35% in Luxemburg to close to zero in Iceland and the United States and slight positive differences favoring women in Hungary and Ireland (OECD, 2007). Parallel gender differences exist in the use of the Internet. The gap increases with age, with a smaller gender gap in access to computers existing among younger women than among older women. But the gap has been closing in many countries over the years, in part due to the increasing number of people who have been exposed to ICT in their youth.

The Economic and Social Impact of Technology

17 http://www.netz-tipp.de/languages.html.
18 http://www.slideshare.net/PewInternet/degrees-of-access-may-2008-data?type=powerpoint
Historically, going back at least as early as the water-mechanized industrial revolution in eighteenth-century England, certain technologies have not only improved processes within the sector in which they were introduced—they went on to have a transformative impact across the economy and society (Freeman and Louca, 2001; Perez, 2002). These technologies were transformative in that they came to be associated with a new paradigm (Perez, 2002)—an interdependent and synergistic set of industries, infrastructure networks, organizational structures, and business and social practices which they supported and upon which they depended. Historically, waves of such technologies—steam power, electrical power, mass production, and now computers—each brought both creative and disruptive forces, forces that restructured the economy and rippled throughout social institutions and practices. The existing paradigm, tuned to a different set of technologies, was not able to cope with or take advantage of the potential offered by new technologies and, consequently, the new technologies were a disruptive force that worked against the current paradigm. Conversely, the new possibilities could not be fully realized until their required enablers were in place and the system became highly tuned to the new paradigm. As the new paradigm emerged, it spun off a whole host of corollary businesses, social arrangements, and cultural practices. In this way, the new technologies were extremely creative forces, as well. Over time, infrastructures, industries, structures and practices became highly tuned to the affordances of the new technologies. These structures and practices also grew to be highly embedded in the economy and society and became the commonly accepted way that things were organized and done. Thus each paradigm shift came to entail a set of all-pervasive principles that became the new “common-sense” basis for organizing any activity and for structuring any institution, be it government, business, entertainment, or education.

The “creative destruction” that occurs in the early phases of a paradigm shift can be violent and painful, as earlier industries, businesses, practices and jobs are displaced or destroyed. New organizations are put in place, new ways of interacting are instituted and new skills are needed, as the desirability of old ones decline. There can be significant dislocation and social inequity. The new wealth that accumulates among the innovators is often more than counterbalanced by the poverty that spreads at the other end, as a result of disruptive forces, and inequity within society increases. Perez’s historical analysis argues that as organizations, practices and people are realigned; the new paradigm fosters a quantum jump in productivity that modernizes and regenerates practically all economic activities. This can result in full employment and the economic and social benefits of the new system become widespread. Socially, a new style of living begins to diffuse from innovators to others, often in more popular versions and variations.

Perez contends that the most recent shift has been from a mass-production paradigm to a paradigm based on ICT and knowledge creation. That is not to say that manufacture, or even agriculture, no longer play a role in the modern economy, but that ICT and knowledge creation have eclipsed manufacture as the primary productive factor. Individual countries, companies, and people may differ in the degree to which or the way in which they are able or choose to participate in this shift and the impact of the shift will differ across them. But as with previous technological revolutions, the destructive and creative impact of the current shift has been profound, as documented by a series of macroeconomic and microeconomic studies.

On the macroeconomic side, every one of the world’s 25 largest economies has shifted from the manufacture of goods to the provision of services. In these countries, services either account for more than 50% of the GNP or they are the largest sector in the economy (Kamarkar and Apte, 2007; Apte, Kamarkar and Nath, 2008). But an even more significant shift within many economies has been from the provision of material goods and services to the provision of information and knowledge. For example in the USA, the manufacture of material goods (such as automobiles, chemicals, and industrial equipment)
and the delivery of material services (such as transportation, construction, retailing) accounted for nearly 54% of the country’s economic output in 1967. By 1997, the production of information products (such as computers, books, television, software) and the provision of information services (financial services, broadcast services, education) accounted for 63% of the country’s output. Information services alone grew from 36% to 56% of the economy during that period. This shift has created new industries, companies, products, services, and jobs, some of which were unimaginable only a few decades ago. People all over the world now use eBay, Google, and Yahoo! every day. None of these companies existed 15 years ago yet they now have a combined market value of more than $200 billion. The proliferation of information products and services is a phenomenon that has come to be called the “information economy.”. This information economy has been defined as an economy wherein the production of information goods and services dominates wealth and job creation (Cogburn and Adeya, 1999)

While manufacturing has decreased as a portion of the economy in developing countries, it has increased dramatically in China, Thailand, Malaysia, and Indonesia. The availability of manufacturing jobs in these countries has pulled millions of people out of abject poverty (Sachs, 2005, 2008). At the same time, development in these countries has created significant problems related to economic inequity, urbanization, pollution, and environmental degradation.

Macroeconomic studies have been complemented by microeconomic studies in the USA (Stiroh, 2003), the United Kingdom (UK), (Borghans and ter Weel, 2001; Dickerson and Green, 2004; Crespi and Pianta, 2008), Canada (Gera and Gu, 2004; Zohgi, Mohr, and Meyer, 2007), France (Askenazy, Caroli, and Marcus, 2001; Maurin and Thesmar, 2004), Finland (Leiponen, 2005), Japan (Nonaka and Takeuchi, 1995), and Switzerland (Arvanitis, 2005), which have found parallel changes at the industry or firm level. Across these studies, highly productive companies have become have become organizationally flatter, decision-making has become more decentralized and participatory, information is widely shared, workers form project teams within and across organizations, and work arrangements are flexible.

These changes in organizational structures and practices have been enabled by the application of ICT for communication, information sharing, and simulation of business processes. But this was not the situation initially. It is important to note that early studies showed an insignificant or even negative relationship between the uptake of technology and productivity, what came to be termed the productivity paradox (Brynjolfsson, 1993). In retrospect, it is perhaps not surprising that new technologies would make little difference early on in corporations or even entire economies if they are used to do the same thing. Indeed, one might anticipate an initial decline in productivity as workers figure out how to use new technologies, such as electronic spreadsheets and word processors, to perform tasks that were previously routine. It was only when ICT investments became connected to changes in organizational structure and business practices that productivity gains were realized. Indeed, a major factor in the success of highly productive, innovative firms is the use of ICT as it is associated with a pattern of mutually reinforcing organizational structures, business practices, and employee skills that worked together as a coherent system (Pilat, 2004; Gera and Gu, 2004). For example, a US Census Bureau study (Black and Lynch, 2003) found significant firm-level productivity increases that were associated with changes in business practices that included re-engineering, holding regular employee meetings, using self-managed teams, improving employee skills and encouraging use of computers by front-line workers. In Canada, Zohgi, Mohr, and Meyer (2007) found a strong positive relationship between both information sharing and decentralized decision-making and a company’s innovativeness. Murphy (2002) found productivity gains when the use of ICT was accompanied by changes in production processes (quality management, lean production, business re-engineering), management approaches
(teamwork, training, flexible work and compensation) and external relations (outsourcing, customer relations, networking). In these firms, ICT was a lever that launched organizational and behaviour changes that brought the practices of these firms into alignment with the new technological, economic and social information technology paradigm.

Changes in organizational structure and business practices and the pervasive use of ICT have resulted in corresponding changes in the skills needed of workers and the hiring practices of companies. A Massachusetts Institute of Technology study (Autor, Levy, and Murnane, 2003) of labour tasks in the workplace found that commencing in the 1970s, routine cognitive and manual tasks in the US economy declined, and non-routine analytic and interactive tasks rose. This finding was particularly pronounced for rapidly computerizing industries. The study found that as ICT are taken up by a firm, computers substitute for workers who perform routine physical and cognitive tasks but they complement workers who perform non-routine problem-solving tasks. Because repetitive, predictable tasks are readily automated, computerization of the workplace has raised demand for problem-solving and communications tasks such as responding to discrepancies, improving production processes and coordinating and managing the activities of others. The net effect is that companies in the USA and other developed countries (Lisbon Council, 2007; European Commission, 2010) are hiring workers with a higher skill set. In the twenty-first century economy and society, the memorization of facts and implementation of simple procedures is less important; crucial is the ability to respond flexibly to complex problems, to communicate effectively, to manage information, to work in teams, to use technology, and to produce new knowledge—capabilities that have come to be called twenty-first century skills (Partnership for the 21st Century, 2005; International Society for Technology in Education [ISTE], 2007; Kozma, 2009; Trilling and Fadel, 2009; European Commission, 2010).

The pervasiveness of ICT has had a significant social impact, as well. The widespread availability of computers has changed the way people access and use information, as well as communicate with others and create new knowledge and cultural artefacts. Studies in North America and Europe show that large numbers of people use the Internet regularly and do so to conduct online purchases, conduct banking transactions, use online chat or messaging, download music or movies, play games, exchange email, and search for information. In Europe, 82% of adults between the ages 45 and 54 use the Internet for email and 91% use it for finding information and online services (Eurostat, 2009). In the USA, according to the Pew Internet and American Life Project, more than half of all Americans turn to the Internet to find answers to common problems about health, taxes, job training, and government services (Fallows, 2008). ICT use is particularly prevalent among the youth. In Europe, 95% of youth between the ages of 16 and 24 use the Internet to find information and online services and 84% use it for leisure activities related to obtaining and sharing multimedia content (Eurostat, 2009). In the UK, 49% of the children between the ages of 8 and 17 who use computers have an online profile; 59% use social networks to make new friends (Ofcom, 2008). A study of online teens in the USA found that 64%, principally girls, participated in at least one form of digital content creation (Lenhart, Madden, Macgill, and Smith, 2007). Indeed, today’s youth are so engaged in the use of technology that they have come to be called the new millennium learners (Pedro, 2006). As well, the broad impact that ICT has had on the world has been captured by the terms information economy or knowledge society, terms that characterize the paradigm shift associated with the information technology revolution.

The global shifts occurring in contemporary economy and society have been usefully characterized and well documented (Friedman, 2006). But Perez (2002) provides a particularly insightful summary and contrast between the technological, economic and social paradigms associated with the mass production and the information technology revolutions:
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<th>Mass Production Paradigm</th>
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<td>Segmentation of markets/proliferation of niches</td>
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<td>Horizontal integration</td>
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<td>Standardization</td>
<td>Heterogeneity, diversity, adaptability</td>
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<td>Functional specialization/hierarchical pyramids</td>
<td>Inward and outward cooperation/clusters</td>
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<tr>
<td>Centralization</td>
<td>Globalization, interaction between local and global</td>
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The primary distinction between these two paradigms is the shift from the production of objects to the production of knowledge. But there are a number of corollary characteristics that support the paradigm. The hallmark of the mass production model is standardization. Standardization of production processes and outputs is necessary to maintain the quality of produced goods, as well as achieve the economies of scale that leads to productivity gains and profit. The standardization of processes and outputs rests on an organizational structure in which a relatively small number of decision-makers and managers direct the efforts of a large number of skilled, semi-skilled, and unskilled workers. In contrast, the hallmark of the information technology paradigm is personalization. Rather than providing a large number of high-quality but identical products to a mass market, the information technology paradigm provides customized services that meet individual needs and preferences. Consequently, the organization structure shifts to make decisions closer to the customer and more responsive to customer diversity and demands. Productivity gains are achieved by increasing the skill of the workforce and distributing operations to lower overhead costs.

The role of ICT is also quite different in these two paradigms. In the mass production paradigm, the information and communications technologies of an earlier time—print, radio, and television—are used to support the dissemination of information from centralized authorities and to foster the consumption of mass produced goods. In the information technology paradigm, ICT serves primarily a productive function, as more people have access to the multimedia, information processing capabilities of computers and are able to use them to create new knowledge. These capabilities allow for a market based more on the personalization and customization of products and services than on standardization and mass production. Networks are used to access and share information and they both enable and reinforce the collaborative relationships that are characteristic of the new paradigm.

**Implications for Less Developed Countries**

While developed counties are engaged in the shift from the mass production to information technology paradigm, the economies of many less developed countries are pre-industrial and based primarily on agriculture. Often these countries suffer from low agricultural productivity, poor coverage of infrastructure and public services, and small amounts of exports, all concentrated in a narrow range of commodities (produce, cotton, etc.). For example, 70–85% of the workforce in most Sub-Saharan African countries is engaged in agriculture while at the same time, Africa is the only continent in the world that has experienced a net decline in per-person food production during last two decades of the twentieth century (Borlaug and Dowswell, 2001). In these economies, living standards are near subsistence or below and most smallholder farm production goes for immediate use rather than to the market. There is little exchange of money and little margin for savings or taxes. Consequently, there is little capital available for private investment or for public financing of the infrastructure needed to foster economic development and the country can be stuck in what economist Jeffery Sachs (2005, 2008) calls the “poverty trap.” According to Sachs, the challenge for policy-makers in such countries is to
acquire the resources from other sectors, perhaps from natural resources, foreign aid, or tourism, to create the conditions under which crop yields increase to the point where smallholders can take outputs to market, improve their living conditions, save, and participate in the formal economy. With increased economic participation, resources become available to lay infrastructure—roads, power grid, ports, primary schools and health system—that sets the stage for further development.

As development continues, savings and investments can increase. Such investments support the development of basic manufacturing capacity that draws on low-skill, low-wage labour and that takes simple, local inputs such as raw fibre and produces low-value products, such a woven fabric or assembled clothing. As industry grows, more people enter the workforce, save and pay taxes. This is the point at which the country can begin to participate in the mass production, manufacturing economy. Capital accumulation is still the challenge in this phase, attracting the large amounts of foreign direct investment that is needed to build a modern manufacturing base that will move up the value chain and provide for a higher standard of living. If successful, these resources can serve as the foundation for even more development and entry into the global economy.

The Role of ICT, Knowledge, and Education in Development
The United Nations Industrial Development Organization (UNIDO) describes a high-road approach to economic development, in which less developed countries use competitive advantages, create a stable macroeconomic structure, liberalize trade, develop human capital and infrastructure, and attract transnational corporations, foreign direct investment, and imported technology (UNIDO, 2002/2003). The approach builds on these investments to move up the value chain and initiate a virtuous cycle of development in which productivity growth, equity, poverty eradication and security can all reinforce one another. Knowledge, education and infrastructure all play particularly important roles in the high-road approach.

Knowledge has some special economic properties and plays a particularly important role in this development (Stiglitz and Walsh, 2002). Unlike raw material, it can be used multiple times without depreciated value, and unlike equipment it can be used by many people at the same time—that is, it is non-rivalrous. Knowledge can also be shared widely at little cost. These facts open the possibility of a productivity factor with compounding rather than diminishing returns—that is, additional investments in knowledge creation can lead to continuous growth. Reviews of macroeconomic studies confirm a strong positive relationship between the investments in knowledge inputs, such as research and development, the generation of knowledge outputs, such as patents, and economic growth (Ulku, 2004; Lederman and Saenz, 2005).

Knowledge creation and innovation depend heavily on high-quality education and a well-developed information infrastructure. The power of this conjunction is witnessed by the 13 countries identified by the Commission on Growth and Global Development (2008) that have crafted policies to create sustained economic growth—an average increase of 7% or more in Gross Domestic Product (GDP) for 25 years or longer. These are countries like Botswana, Brazil, Indonesia, Republic of Korea, Singapore, and Thailand—countries that were poor 35 years ago. Every country in this study put substantial effort into schooling its citizens and deepening its human capital. Indeed, the development of human capital was one of the principal means by which government policy was used to support economic development in these high growth countries. Conversely, the study found that no country had sustained rapid growth without also keeping up impressive rates of public investment in infrastructure and education.
Education earns a high return on investment; this is supported by the results of both international microeconomic and macroeconomic studies. Microeconomic studies focus on the benefit of educational investments to individuals while macroeconomic studies focus on returns to the economy more generally. Microeconomic data from 42 countries found that an average rate of return for an additional year of schooling was a 9.7% increase in personal income (Psacharopoulos and Patrinos, 2002). A cross-country macroeconomic study found that there was an additional 0.44% growth in a country’s per capita GDP for each additional average year of attained schooling—a return on investment of 7% (Barro, 2002). Other studies have found returns that go as high as 12% (Sianes and Van Reenen, 2002; Stevens and Weale, 2003). The quality of education has an even stronger relationship to growth than did the duration of school participation; the amount learned was more important than the number of years of schooling. Barro (2000) found higher test scores of one standard deviation equated to 1% growth in per capita GDP. More recent studies bear this out. Hannushek and Woessmann (2009) found strong, independent relationships between increases over time in both basic literacy skill levels and higher levels of cognitive skill and a nation’s increases in economic performance. Similarly, Zagler and Zanzottera (in press) found that an increase of 10% in those scoring at the 95 percentile on an international science test would predict a 1.5% higher rate of growth in a country’s economy.

Research reviewed earlier in this chapter illustrates the impact that ICT has had on the societies and economies of developed countries. But ICT can make significant contributions in less developed countries, as well, particularly ICT uses that are appropriate to local needs and in local languages (Slater and Tacchi, 2004; Weigel, and Waldburger, 2004; Gerster and Zimmerman, 2005). ICT projects using a range of technologies, including computers, digital cameras, handheld devices, television, and radio, have demonstrated their value in locally-identified areas of need such as health, agriculture, and, of course, education. With these resources, rural women in India form local knowledge networks to specify information needs, locate information resources and write and share diaries and newsletters in the local language (Pringle and Subramanian, 2004). Local youth from poor families in Nepal learn how to produce local multimedia content using a range of online resources, digital tools, and community media through access to the village telecentre, equipped with audio and video production facilities and cable network. Pastoralists in the Sahel use networked computers, GSP, and cell phones to manage grazing and water resources, to search for new pasture and watering points during seasonal flock migrations, and to speed up the exchange of information and provide them with an “early warning system” against pending disasters (Batchelor, et al., 2005). Villagers in Uganda and Tanzania use community radio, computers, and cell phones in local telecentres to access information on markets, farm inputs, crop management and local affairs (Kozma, 2006). Rural Philippino farmers, fishermen, and small and medium owners use cell phones and the Internet to access market prices and to trade products (Batchelor, et al., 2003). Villagers throughout Indonesia use Internet kiosks and CD-ROMs to access information on agriculture, fisheries, animal husbandries, food technologies and recipes, and traditional medicine (World Bank, 2005). With a national network of Knowledge Stations in Jordanian communities, youth, women, poor, illiterate groups, unemployed and micro- and small-scale entrepreneurs in deprived areas have access to information, training on the use of computer technologies, and ways of utilizing the information available on the Internet to enhance their own livelihoods and capacities (Nusseir, 2005). And Brazilians have access to a range of government services, via the Internet, such that 90% of them submit their annual tax statements online (United Nations Economic Commission for Latin America and the Caribbean, 2002).

However, investments in economic growth do not guarantee equitable, broad-based social development. They could merely benefit the elite of a country and distant owners and executives of transnational corporations. Consequently, there are those who take a profoundly different position than
the “New Growth” approach offered by UNIDO and argue that morality as well as economics drives development. Poverty, they contend, will not end without a dramatic, global redistribution of power and wealth that was acquired as a result of centuries of colonialism (Unwin, 2007). Clearly, as the UNIDO report (2002/2003) points out, development also has a low road. Confronted with intense global competitive pressures, developing countries may be tempted to take the low road and foster development by devaluing exchange rates, disregarding labour or environmental regulations, and reducing wages, only to enrich the few and perpetuate social inequities. But for those policy-makers who choose the high road, development policy and programs can build the infrastructure, human capital, and knowledge needed to fuel economic productivity, while promoting social equity and broad-based prosperity.

The Impact of ICT on Education

Apart from research on the relationship between ICT and economic development, education policy-makers want to know the research findings that test the hype and bold claims of technology advocates. They want evidence that justifies the significant financial investments that are needed to integrate ICT into the education system. They want to know if the use of computers makes a difference in teaching and learning.

Many studies have been conducted to evaluate the educational impact of computers. A comprehensive review of this research is beyond the purpose of this paper. But this section provides policy-makers with a sense of what the research says about the impact of ICT on students, classrooms, and schools. However, it is important to keep the broader context of this research in mind. The research conducted so far on the impact of current ICT was done within education systems that, like other components of society and the economy, have become highly tuned to the mass production paradigm. For the most part, research to date has examined the impact of ICT on traditional goals, as it was used in traditional classrooms. Results from this research can inform policies and practices that target the effectiveness or efficiency of the system as it is defined within the current paradigm. But the research to date has relatively little to say about the role of ICT within a new educational paradigm and its role in educational transformation. It is research on what education is, rather than what it could be.

Student outcomes. A primary concern of policy-makers faced with making significant investments in equipment and software is whether student access to and use of ICT will increase the learning of traditional school subjects. Empirical studies to date show an inconsistent relationship between the availability or use of ICT and student learning. Some studies show a positive relationship between computer availability or use and achievement; some show a negative relationship; and some show none. For example, two major studies in the USA found a positive relationship between availability of computers in schools and test scores (National Centre for Educational Statistics, 2001a, 2001b). A study in Australia (Banks, Cresswell, and Ainley, 2003) found no relationship between computer availability in schools and test scores. And two large studies, one an international study (Fuchs and Woessmann, 2004) involving 31 developed and emerging countries, and another using a US sample of schools (Wenglinsky, 1998), found a negative relationship between the availability of computers in the home and achievement scores.

Digging more deeply into these and other student outcome studies, it becomes clear that the connection between ICT and student learning is a more complicated relationship than one based on mere availability or use. Despite an otherwise negative relationship, when Fuchs and Woessmann (2004) compared the use of home computers for communication or educational uses of home computers, rather than for gaming, they found a positive relationship with achievement. In a more recent study in
OECD countries (CERI, 2010), there was also a significant correlation between frequency of home use of computers and achievement on an international science assessment, even when socioeconomic contexts are controlled. School use is another matter: in the majority of OECD countries, students of different levels of ICT use in schools all performed similarly on the science assessment. However, it was found that while a majority of students participating in the study were regular users of computers at home, they did not use them regularly in school.

Even these analyses must be qualified. It matters how ICT is used and what is tested. Student assessments were specific to the learning of mathematics and reading in the Fuchs and Woessmann study and of science in the CERI study. But the data collected on computer use was general; even the educational use computers was not specific to math, reading, or science. Some studies have looked at this more-direct relationship between the topic of use of ICT and the topic tested. For example, the Wenglinsky (1998) study cited above, measured the amount computers were used in mathematics classes and scores on math tests. The study found a positive relationship between the use of computers and learning in both 4th and 8th grades. Similar positive relationships were found in more recent studies where computers were used and students tested in mathematics (NCES, 2001a; Cox 2003), science (NCES, 2001b; Harrison, et al., 2003), and literacy (Harrison, et al., 2003). Still, some studies in mathematics found negative relationships between computer use in math and math scores (Angrist and Lavy, 2001; Pelgrum and Plomp, 2002).

Even here, the results of these studies must be qualified. Conclusions in these studies are limited by the fact that they use correlation analyses. This is the most common type of ICT study. But with this type of analysis, factors are simply associated with each other; causality cannot be established. Yet, this is the issue of most concern to policy-makers. It cannot be assumed that positive results in such studies were due to computers because, for example, it may be that the brightest students use computers more than less able students and it is student ability that accounts for higher scores rather than computer use. Causality can only be assured with controlled experiments, where one group uses computers or uses them in a certain way and an equivalent group does not. An example of this type of experimental study was conducted in Vadodara, India (Linden, Banerjee, and Duflo, 2003) in which students in primary schools used computer mathematics games two hours a week and students in equivalent schools did not. The students who used computers scored significantly higher than the comparison students on a test of mathematics. The bottom group of the students benefited most, and girls benefited as much as boys.

Even with experimental studies, conclusions can be drawn with confidence only when results are consistent across a substantial number of such studies. Kulik (2003) looked at a large number of studies in the USA that were carefully designed and he combined the results in a meta-analysis to statistically compare outcomes across studies. His findings across 75 studies can be summarized as follows:

- Students who used computer tutorials in mathematics, natural science, and social science scored significantly higher on tests in these subjects. Students who used simulation software in science also scored higher. However, the use of computer-based laboratories did not result in higher scores.

- Primary school students who used tutorial software in reading scored significantly higher on reading scores. Very young students who used computers to write their own stories scored significantly higher on measures of reading skill.
• Students who used word processors or otherwise used the computer for writing scored higher on measures of writing skill.

Means, et al. (2009) also conducted a meta-analysis of ICT studies. This team examined carefully designed studies of online versus face-to-face learning in K-12 settings published between 2004 and 2008 and identified 51 effects. Across studies, online learning was significantly more effective than face-to-face. Situations that blended online learning and face-to-face learning were even more effective.

Beyond an impact on achievement in traditional subject areas, a number of ICT studies have established that computers can have a positive effect on student motivations, such as their attitudes toward technology, instruction, or the subject matter. For example, the Kulik (2003) analysis found that students using computer tutorials also had significantly more positive attitudes toward instruction and the subject matter than did students receiving instruction without computers. This finding corresponds to that in elementary schools in Japan (Ando, Takahira, and Sakamoto, 2004) in which students who used the Internet for Web browsing and message posting reported increases in positive attitudes toward learning. In a comparative study conducted in physics classes in Kenya (Kiboss, 2000), two randomly assigned classes used computer-based instruction while a third equivalent group did not. Students in the computer sections learned physics concepts better and expressed positive attitudes about their physics learning, as ascertained in interviews at the end of the lessons. Nonetheless, there are few studies that go beyond traditional measures of student learning to include such outcomes as creativity, complex problem solving, collaboration, and the ability to learn and even fewer that do this in the context of developing countries.

Impact on diverse students. An important Millennium Development Goal is to achieve gender equality. If girls are to leave school ready to participate equally in the economy, they, too, will need the benefits of ICT—increased knowledge of school subjects and new skills, including ICT skills. However, much of the research in OECD countries shows a gap such that boys have more experience with technology than girls and that girls are more anxious about technology than boys (Blackmore, et al., 2003). Fortunately, studies also show that greater experience with computers results in improved attitudes among girls. Many technology-supported programs in developing countries focus on including girls’ use of computers and data on the impact of these programs often shows no gender gap. For example, girls and boys learned equally from the use of computers in the Vadodara study cited earlier (Linden, et al., 2003). In the World Links evaluation, teachers reported no difference between girls and boys in a wide range of learning outcomes related to computer use (Kozma, et al., 2004). In Andhra Pradesh (India), Wagner and Daswani (2005) reported that poor girls learn more than boys in a non-formal ICT-based literacy program, when controlled for schooling.

Teacher skills and practices. Many governments are using the introduction of ICT as a way of providing teachers with new skills and introducing new pedagogy into the classroom. For example, teachers participating in the Enlaces program in Chile received two years of face-to-face training totalling at least 100 hours of contact (Hepp, et al., 2004). As a result teachers acquire familiarity with computers and use them regularly for professional (e.g. engaging in professional circles, e-learning), managerial (e.g. student marks, parental reports) and out-of-classroom tasks (e.g. searching for educational content on the web, lesson planning). In a survey of teachers in 12 countries in Sub-Saharan Africa and South America, Kozma, et al. (2004), found that teachers who participated in a training program on how to integrate computers into their instruction were much more likely than non-participants to report that their students engaged in a variety of innovative pedagogical practices, such as gathering data for a research project, collecting information about another country or culture, and collaborating on a project with students from another country.
**Access, barriers and use.** ICT can provide students with access to educational resources that might not otherwise be available. For example, traditional broadcast media, can provide large numbers of students efficient access to lessons and courses, as in the case with educational television used by millions of secondary students in Mexico and Brazil (Wolff, et al., 2002) and millions of primary students in Egypt (Ward-Brent, 2002). Increasingly, networked computers are being used to provide access to instruction for secondary students, although not nearly to the scale of broadcast media. For example, in a virtual high school program in the USA, thousands of students across many states enrolled in the programme to take a variety of online courses that would not otherwise be available to them in their own schools (Zucker and Kozma, 2003).

However, regular access to networked computers in schools is still limited in many countries, particularly developing countries. A recent international study of educational ICT in 23 educational systems in North America, South America, Europe, Africa and Asia found significant differences between countries in the availability networked ICT in schools (Law, Pelgrum, and Plomp, 2008). For example, in Norway and the Province of Alberta in Canada, nearly 60% of schools had a ratio of less than five students per computer. In Finland, Denmark, Singapore, Hong Kong, and the Province of Ontario in Canada, 80% or more of the schools had a ratio of less than nine students per computer. In contrast, a majority of schools in Chile, the Russian Federation, South Africa, and Thailand had between 20 and 40 students to a computer.

Schools in developing countries encounter many barriers to the use of ICT beyond access. In the evaluation of the World Links program (Kozma, et al., 2004), schools in South American and African countries identified barriers that ranged from lack of access to computers in working order, to lack of software, technical support, administrative support, sufficient teacher training, internet access, and even lack of a reliable supply of electricity.

But even when resources are available, as in OECD countries, the use of ICT is not a central everyday feature in many classrooms. A survey of headmasters and teachers in 27 European countries found that nearly 100% of schools have access to computers and 96% have access to the Internet (Empirica, 2006). Nearly 100% of teachers in Europe have used computers and almost all have used the Internet. However, the most common use of computers by teachers was to prepare lessons; 89% of the teachers responding to the survey said that they had used the computer for this purpose over the 12 months prior to the survey. And while 74% have used a computer in class, 63% said it was used to support presentations. Of the teachers responding, 66% said that they had students use computers in class during the past year but of these 62% said they used it in less than 25% of their lessons.

In the Law, et al., study (2008), the typical response of 8th grade mathematics teachers about the use of a wide range of educational applications for ICT was somewhere between “never” and “sometimes”—whether in Singapore or South Africa. The three most common pedagogical practices in these classrooms were having students fill out worksheets, work at the same pace and sequence, and answer tests. These findings convey the limited extent to which the information technology paradigm has been incorporated into educational systems around the world. Education systems have yet to cross a threshold of significant ICT use and, as such, it is likely that ICT will have only a minimal impact on students and teachers. The low use of ICT in schools is in sharp contrast to businesses in the knowledge economy where computers are integrated into everyday practice and their use is central to business success.
Summary and Implications

While ICT have had a significant impact the global economy and on the way people around the world work, live, and play, they have yet to have a significant impact on education practice and on what and how people learn in schools. The marginal impact of ICT on student learning is reminiscent of the findings from early research on the economic impact of ICT. In the business sector, ICT did not have an impact on productivity until it was accompanied by a cluster of other changes that transformed the economy and brought companies into alignment with the information technology paradigm spawned by the new technologies. This shift has yet to happen in schools. The vast majority of educational systems, schools and classrooms around the world still participate in the mass production paradigm and technology is rarely used, even when it is readily available. What are the conditions under which ICT can make a difference? What policies and programs are needed to transform education? These are the questions addressed in the next chapter.

References


