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EMERGING TRENDS IN ICT AND CHALLENGES TO EDUCATIONAL PLANNING

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INTRODUCTION

This year I turned 60, yet several years ago, a modern machine I had used was placed in a museum. It is an IBM 1401, which graduate students in the Department of Social Relations learned to use when I came to Johns Hopkins University in 1966. First we loaded a deck of punch cards to make the compiler read our programs. We then mounted magnetic tapes; they moved in a staccato rhythm to read what corresponded to punch cards. Sometimes it was quicker to use the old sorter-counters—they sorted and counted the punch cards mechanically. It was nice to watch as the cards piled up, and you could see your hypothesis confirmed or invalidated by the relative size of the resulting stacks of cards—science, indeed, in the making. It was not so nice, however, when the sorter-counter, like a mechanical dog, ate the cards. Now this IBM 1401—which has been called the Model T of the computer revolution—is stored in the Smithsonian Institution in Washington, DC.

The Hopkins 1401 had 8k of memory. Nowadays, I carry an iPaq personal organizer in my pocket, which has 32 Mb of memory. It keeps a schedule, address book, various calculators, world timer, documents in Word and Excel, and e-books such as Machiavelli's *The Prince*. And I can download music from the Internet as well.

At Hopkins, we were among the first to be exposed to learning by the new information and communications technology. Via teletypes, we could access a remote computer located, I think, somewhere in Pennsylvania. On it was stored a program by which we could learn interactively different statistical techniques, such as ANOVA or regression analysis. We could choose the parameters (such as the grand mean and within-row means) and then add a normally distributed error term to generate data with a chosen standard deviation. We could then order the logical building blocks (such as "total sums or squares") and use them to see what could be retrieved as estimates of the parameters we had put in, and how sensitive the results were to standard deviation of the error term we had chosen—e.g., the "estimated" grand mean compared to the "true" grand mean we had entered. Such programs were designed by the legendary sociologist, James S. Coleman, together with Doris Entwistle. I still rank the course they designed as one of the best statistics courses—indeed, one of the best of all courses—I ever took.

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THE ICT REVOLUTION(S)

I am telling this story to make two points.

- The speed with which the revolution in information and communication technology (ICT) has taken place is phenomenal. My grandfather grew up in a society without the telephone, my father in a society without radio, I in a society without television, and my son in a society without the Internet.
- The changes the ICT revolution has wrought are not limited to one single sector of society, nor do theyjust add another column in the aggregate tables of macroeconomists. ICT transforms all sectors of the economy. The car I now drive has more microprocessors than the university where I started in 1960. Hospitals would have to close and airlines would have to be grounded without them. My uncle's hearing aid is a wonder of transistors and miniaturization. My PC now serves as a post office, word processor, bank window, shopping center, CD player, photo shop, news medium, and, of course, a vast library. The changes have been faster, deeper, and more sweeping than anyone imagined as late as two or three decades ago—even by those who have pushed the new frontier.

It also can be argued that talking about "the ICT" revolution is a misnomer; for there has not been one revolution, but five—so far.

Revolution 1: The Computer

The first revolution started during World War II, with the first large, automatic, general electromechanical calculator, Harvard Mark 1. It was 50 feet long, eight feet tall, and weighed five tons. A couple of years later, ENIAC was presented in Philadelphia, based on radio tubes and practically without any internal memory, yet using 18,000 vacuum tubes and weighing 30 tons. Each time a new task was to be performed, some 6,000 switches covering three walls had to be thrown. In 1947, Walter H. Brattain, John Bardeen, and William Shockley created the first transistor, and, on its basis, faster and more powerful computers were constructed. "Computers" became a new catchword, and input-output technology graduated from punch cards to magnetic tape, faster printers, and more languages for programming. Applications also were expanded, from use in academic research to weather forecasting, from airline ticketing to accounting. This development continues; the first ICT revolution is still under way.

Revolution 2: The PC

The second ICT revolution has its roots in the 1970s, when the first "processors on a chip" and magnetic discs were constructed. But as late as 1977, Ken Olson, the legendary president of the computer company, Digital, stated: "There is no reason anyone would want a computer in their home." He was definitely wrong. In the same year, Steve Jobs and Steve Wosniak started to sell their Apple II, and Bill Gates and Paul Allen had already founded a firm called Microsoft. From being an esoteric toy, the personal computer gradually became a valuable tool for word processing, accounting, and, after a while, pictures. IBM, which at first grossly underestimated the markets for the personal computer (PC), launched its first machine under that name in 1981. Now the PC has become as widespread as the radio when our grandparents were young—indeed, as widespread as bicycles are among today's youth. This second ICT revolution continues like the first: the capacities of the machines increase, their applications expand, and the number of people who use them multiplies.

Revolution 3: The Microprocessor

The third ICT revolution is that microprocessors have become embedded in an ever-widening range of products: the steering systems of airplanes, the control panels of hydroelectric power stations, domestic air conditioning systems, the traffic lights in our streets. Even when we do not recognize it, they have become part of our everyday lives: in video players, credit cards, remote controllers, cameras, hotel room door locks, and smart buildings. There is a microprocessor embedded in our digital scale in the bathroom. If you use an electric toothbrush, its functions are governed by some 3,000 lines of programming. Microprocessors translate bar codes into prices at the cash register, monitor electronic injection of fuel in our cars, and determine where the elevator stops in our building. An ordinary household now contains some 100 microprocessors, in everything from dishwashers to alarm systems. Microprocessors constantly expand their capacity, applications, and users.

Revolution 4: The Internet

The fourth ICT revolution stretches back to the late 1960s, when the U.S. Department of Defense drew up guidelines for a communication network among computers (ARPANET). After a while, universities in and outside the United States were hooked up to it, and some started to use it to send messages. France developed its variant—its Minitel system—at the beginning of the 1980s, at the same time the U.S. National Science Foundation set up its own network among academic institutions that later became part of Internet. A dozen universities on the U.S. East Coast with IBM mainframes contributed with BITNET. In Europe, EARN became a network among academic institutions, while CERN in Geneva was crucial in the development of the World Wide Web, which got its name in 1990. A couple of years later, surfing on the 'net started, and more and more people hooked up. A PC needed a modem to use its potential fully. This fourth ICT revolution continues like the others as more and more computers are interlinked with an ever-growing number of "servers" and an expanding range of applications. Yet, the most important part of the fourth ICT revolution was this: on the computer networks engineers had constructed, users built social networks to make them useful and effective—in this case, the social superstructure built on the material basis became really super.

Revolution 5: Wireless Links

The fifth ICT revolution was linking without lines—the new possibilities opened by mobile phones. At first, they were big and bulky. Reduction in size and weight was accompanied by expansion of reach and functions, and miniaturization was accompanied by multifunctionality. Mobile phones could be used not just for talking, but also to exchange messages, receive news or stock exchange quotes, review restaurants, or order movie tickets. Phones are no longer only for transmitting phonemes; now they can transmit written messages, pictures, and music. Linking without lines now takes place not just intercontinentally via satellites, but also via high-frequency short-range radio transmitters covering a specific area or cell (hence the name, "cellular phones") and inside buildings by "Bluetooth" and infrared light. (For more on this topic, see chapter 6.)

IMPACT OF THE ICT REVOLUTIONS

I am reviewing these emerging trends to make four general points:

- The speed and impact of the ICT revolutions provide modern illustrations of Says's law: Supply creates its own demand. Contrary to Ken Olson's prediction, PCs have become household appliances. When they were linked via telephone lines, they were transformed from isolated stations to nodes in networks, and their usefulness increased exponentially with each additional node. When new functions were added—access to libraries, e-mail, etc.—their value multiplied. PCs, their links, and their multiple functions were innovations that soon became necessities.
- The way the hardware of ICT was produced and operated has itself become *one of the foremost expressions of globalization;* components come from all continents—chips from Asia, software from America, mobile phones from Europe. Brand names have instant recognition around the world: Acer, Sony, Intel, Microsoft, and Nokia. On the other hand, satellites orbiting the globe allow for instant communication on an unprecedented scale.

- The development of new products and services was part of a vast *distributed and yet integrated global division of labor,* whether it was in the development of new for-profit products and services or the more altruistic open-source contributions from a diverse crowd of enthusiasts (such as development of the Linux operating system.)
- The new links—the Internet and the World Wide Web—became the first *truly dynamic and interactive network* that individuals could access from all over the world. Much of what is on the Web is not mass communication in the classical sense: one source, one way, many users. It is by and for interacting people. Indeed, in many respects individuals were ahead of institutions in realizing the Web's potential. For example, music was swapped via the Internet before it became commoditized. Now the passport to world citizenship has become "@."

The ICT revolution has been very much about spotting opportunities and inviting everybody to learn to make good use of them. Indeed, the ICT revolution is perhaps above all else a revolution in learning. Individuals have seen the potential of the new tools and introduced them into their homes on a vast scale. Firms have applied them to an ever-widening range of activities: bookkeeping, production control, management, communication, marketing, and drug development. Public authorities have incorporated them into all of their activities, from vaccination programs to tracking criminals.

REVOLUTION IN LEARNING

Since the ICT revolution is a revolution in learning, it also has transformed available technologies, the means and methods of studying, the modalities of school operations, the manner of investment and expenditure of resources, and the very way we think about what education could be and should do.

Even before the Internet became a new mode of communication, and the World Wide Web made it possible to access learning material anywhere, universities had started to use telecommunications and computers for teaching, as illustrated by my experience at Johns Hopkins University in 1966. But with the advent of the Internet and the Web, these opportunities have expanded vastly, and educational institutions have made more and more varied use of them. Course material is posted on the Web, assignments can be communicated through the 'net, and teachers can be accessed around the clock by the new modes of transmission. The new education programs have *reached out* to off-campus students, often from long distances, but they also have *reached in* to regular students in novel ways by providing learning materials in new forms. They include a wide spectrum, from French grammar to fractal geometry, from guides to trilobites to flash cards for physics.

The Internet also changes the ways schools work by making possible closer cooperation and interaction among them, within the same country and across continents and oceans. One example is joint "virtual projects." Likewise, parents can be kept informed via the Websites of schools—virtual PTAs, so to speak.

Not only has ICT transformed the way learning institutions work, it also has changed the way we think about organized education. ICT has become a medium in the original sense of the word: something in the middle, between the substance to be learned and the student who is to master it. First, it liberates provision of education from the constraints of time and place: many courses can be accessed from more or less anywhere and at any time. Second, training can be customized, by allowing material to be adapted to individual levels and tasks to be paced according to personal progress.

But tailored capacity and development does not mean that students cannot interact—individualized does not mean isolated. To the contrary, the physical network allows students to work together, whether for mutual consultation and advice or support and encouragement. Hence, the new education technologies alter the means and modes of studying. Students can link to other students, across boundaries and across continents. Children can take part in the development of learning materials for each other in other classrooms or countries. Teachers in the remotest places can be encouraged to take part in important professional development projects. Indeed, the whole education system can work like a neural network, where cells with synapses to other cells can fire them up.

The Internet also can become a network for altruism. Institutionally, so much on the Web is there for free and for all. A large part of the available educational resources is created by groups outside of schools and academic institutions, yet is free for all and provides excellent inputs for learning (such as the learning material from the Smithsonian Institution or the World Health Organization [WHO]). Sometimes, such worldwide community service is well organized, such as the scanning, typing, or proofreading of classical texts that are entered on Websites open to all, or when the classification of craters on Mars is set up as voluntary work among informed amateurs linked by the Internet. Individually, some communities have experimented with tutors mentoring students from home. Such acts of generosity allow those participating in them to engage their minds and help others; it sure beats the millions of clicks wasted on solitaire.

CHALLENGES TO EDUCATIONAL PLANNERS

The ICT revolution offers new intrinsic opportunities; it dramatically changes what can be learned and by whom as well as what can be produced and provided by whom. These potential changes, however, pose many new challenges for educational planners. These challenges can be divided into two broad types: those that pertain to equity and those that pertain to quality. But unless educational planners respond to these changes and challenges with commensurate speed, they will become, so to speak, technologically challenged.

Equity

Although in many Western countries, the majority of households have PCs linked to the Internet, considerable differences remain along regional and class lines. Several studies document that boys are more active than girls in using the new technical tools. And though schools also are increasingly well equipped and connected, standards vary within countries with educational level and type. The same applies to teacher training and skills.

This raises the broader question of equity: within countries as well as between countries, particularly between the industrialized and developing world. It is true that millions of PCs are sold every year and millions gain access to the Internet. For example, in Norway, more than half the population is connected to the Web, and some 80% have mobile phones. Yet, half the world's population has yet to make their first phone call. There are as many telephones in Tokyo or Manhattan as in the whole of sub-Saharan Africa. Malaysia is different from Madagascar. Shanghai is very different from its hinterlands. In many countries, practically all the telephones are found in the capital: Bissau has more than 95% of the telephone lines in Guinea-Bissau, and Freetown has more than 85% of the lines in Sierra Leone. A majority of villages in many developing countries lack electric power, let alone Internet connectivity. Elsewhere, there has been a gradual deterioration of public services—access is poor, functioning is irregular, prices are high, and service is scanty.

Hence, the pressing problem for educational planners is how to reach, within a reasonable time, the needs of the majority who are poor, uneducated, and live in rural areas: how to fund, implement, and maintain the educational part of ICT networks. This question is all the more pressing because most major international teleoperators do not include sub-Saharan Africa or the remote areas of Central Asia in their business strategy plans. The bitter fact is this: What happens in a country does not depend on the state of the art, but on the state of its economy as well as the state of its state: its system of law, the functioning of its institutions, and the workings of its civil society.

The question of equitable access is not just a question of who can *use* what is available on the Internet, however, but also of who can *produce* it. There are already great differences across countries in this respect. Similarly, there are great differences between corporate actors, public as well as private, in their capacity to become—to use the current jargon—"net-based education providers." Many countries have adopted ICT policies for their education systems that cover not only hardware and infrastructure, but educational materials available for schools and students as well. Such materials, increasingly available on the Internet, range from mathematics resources in Norway to lists of recommended books for California's schools. They can be accessed freely by both domestic and foreign users. In addition, many teachers and professional associations make their best work available free for anyone to use. For example, a simple search for the "Pythagorean theorem" on the Web yields more than 10,000 sites, many of which make available all kinds of useful material—e.g., animated proofs that are much easier to follow than their textbook equivalents. In this sense, the Internet is the greatest venue for exchange of educational good deeds ever constructed.

And this is not all. Education equals finance—public funds to be spent and private demand to be targeted. Hence ICT, and particularly the Internet, is not only an arena for altruism and experiments, but also for business, entrepreneurship, and, sometimes, exploitation. In other words, education is increasingly becoming a market, and a global one at that. In a market, there are customers and producers. And access to the production side of this market is even less equitable than access to its usage side.

Some nations also actively promote programs for foreigners by distance education via the Internet. Australia is a prominent example, where services from its educational institutions have grown into a whole export industry. This is a very interesting and, in many respects, auspicious development, but it also raises a whole range of questions for educational planners about quality, certification, and accreditation. It is notable that the World Trade Organization is considering proposals to add the import and export of higher education courses to its protocols on services marketed internationally; "education products" can then be traded as a commodity from one country to another. This development provides further opportunities for students. It releases education from national control, and it makes the market a stronger force in the globalization of education. On the other hand, planners and officials in developing or smaller countries may face an expanding international market with powerful actors and many new ventures about which they have imperfect knowledge, exercise scant control, and have few possibilities for participation.

Thus, the issue of equity pertaining to ICT has to be addressed along two dimensions:

> equitable access of students as consumers, where the poorer peoples and nations are put at a disadvantage; and
> equitable provision of content, where the poor are even worse off.

Ideally, one wishes for equal opportunity to participate. But access for different actors—both as users and producers—is weighted by their resources. Hence, initial differences are often reproduced, reinforced, and even magnified. (Most of what is provided on the Web comes from the wealthier nations of the Northern Hemisphere.) A formidable challenge, therefore, continues to face planners of international education: how to define the problem and provide assistance for development.

Quality

As ICT is rapidly becoming an integral part of the social environment and as our jobs are being transformed rapidly into tapping on keyboards and looking at screens, traditional literacy is no longer sufficient—what could be called, "Iteracy," becomes imperative. Learning to work a PC and surfing the Internet is becoming crucial for functioning in the workplace, for effective citizenship, for entertainment, and for personal growth. With the rapid change in technology, training cannot be a one-shot affair; we have to be updated continuously to stay abreast of developments. Planning and designing educational systems so that they familiarize students with a technology that is being modified and evolving continuously is not just an intellectual challenge, it is also an economic one.

This problem is exacerbated by the fact that many vendors of new technologies are sometimes more pushers than providers, promoting solutions that have a short useful life or little compatibility with what emerge as industry standards. The history of information technology is not just a history of innovation but also a history of misguided investments.

This situation applies to hardware as well as to "learning packages" and software that promise more than is delivered. What is bought is often expensive and inappropriate, resulting in costly mistakes, not just in economic terms, but in terms of time stolen from students who would have been better off using more proven methods of learning. One could generalize Robert K. Merton's term, "the fallacy of the latest word," to describe this phenomenon. Sometimes new solutions are pushed by politicians and ministers as well: they feel they need to prove they are "modern" by going for gadgets, but they are out of office when the negative results are in. Moreover, it takes time to discover where the potential of ICT in education can best be tapped, and as technology itself is changing, final solutions will continue to evade us.

The learning process also may be skewed in unfortunate directions. Much is made of the fact that ICT has become increasingly "interactive." Learning programs can be tailored to each student, learning at his or her own pace, and being introduced to more challenging tasks as learning proceeds. However, interaction in learning cannot be restricted to person-machine relations; person-person relations will always remain crucial. In industrialized countries, no previous generation of children has had so little contact and communication with the world of adults. Learning has become more age-graded, as has all social interaction. TV, videogames, and Internet-provided pictures and music draw the young into a more virtual world. Hence, rather than formal education also placing students increasingly in front of a screen, planners must be concerned that students are engaged in more real than virtual interaction and connected to actual adults rather than just to their products. Children and youth need positive feedback from applets, but they also need to be seen and respected by peers and grown-ups as real people.

What holds for the educational process also holds for educational content. Demand-driven education means, increasingly, education that is "just in time" and "just enough." Learning what is deemed not immediately relevant may be discarded as definitely wasted. But this concept of knowledge and skills is a perversion, even of a utilitarian justification of it. It is a perversion of the rationale for a broad liberal arts education where the goal is not just to enable one to solve a problem at hand but to develop abilities as a human being to perceive and to participate, to experience, to empathize, and to excel. But then the whole diversity of one's talents must be nurtured and developed. Education, after all, means to "lead out," within and beyond one's present confines, by bringing out latent abilities and talents.

There is another issue with demand-driven education as it is commonly practiced. The growth in knowledge does not just generate a steady stream of new facts, findings, and products—about viruses, proteins, or superconductors. It also means that older knowledge becomes superseded. For instance, it is no longer useful to know which electronic vacuum tubes could be used in a computer. But new facts and data do not only mean that knowledge may become obsolete. They also mean that certain types of established knowledge become more important. The Pythagorean theorem is as valid today as it was in Greece 2,500 years ago. The Linnean system for sorting plants from the mid-1700s is at the heart of classifications still used today. The periodic table of chemistry is as valid at the start of the 21st century as it was at the end of the 19th. French irregular verbs remain as irregular as when I encountered them in high school. In short, there are fundamental frames of reference that are imperative for interpreting new information, for searching for new facts, and for new everyday applications. Knowledge of such valid models, concepts, and theories determines what we grasp of what is unknown. The discovery of DNA does not overthrow molecular chemistry; it extends its uses in biology. Hence, the stream of innovations and findings, more than ever, requires fundamental knowledge—i.e., systems for interpretation and reconstruction. Without familiarity with such systems of reference, the explosion of knowledge leads only to more confusion. Also, from a social point of view, it is the acquaintance with such frameworks that makes it possible to meet new challenges and that prepares us to gain insight, review the situation, and renew strategies; it was general knowledge about retrovirus that made it possible to quickly identify the cause of AIDS.

Even from a purely utilitarian view, "just in time" and "just enough" knowledge is misguided. First, it takes knowledge to know what you need to know. Second, truly new insights are often the result of serendipity—the happy chance combination of seemingly unconnected ideas to a new conception. "Just in time" knowledge is, in practice, often too late, and "just enough" knowledge often makes you miss the critical piece to solve the big puzzle.

The general point is this: Educational planners have to consider what a well-rounded education is. The whole point of education as a common human enterprise is that no student can bring out his or her potential if left to the student's own haphazard personal search. Students have to be led out, "educated" in the original sense of the word.

Finally, one may ask: Is ICT-assisted education better or worse than traditional education? The answer is, probably both. ICT does not suit all students, all subjects, or all phases of learning equally well. There are already considerable differences say, between the offerings in mathematics and history compared to those in music and physical education. Much depends on how ICT-assisted learning is done, and, as in traditional teaching, there are no fast formulas. Discovering and developing the potential of ICT will surely take time, and what we find may not be valid for all time because the context surely will change. Technology in itself is not a panacea; uploading Web content in different subjects does not in itself result in quality teaching or effective use. Teachers have to be trained and need to feel knowledgeable and skilled—not always easy in an environment where young students are often quicker than their teachers to learn new technologies. On the other hand, the lack of willingness to mobilize the young to learn from one another—in the same way as they learn the tricks of new video games—is not only old-fashioned but even counterproductive. Educational planners can focus no longer just on how to secure implementation; they need to arrange for continuous experimentation and innovation to learn by doing in an ever-changing environment where even what is being learned and done is changing.

CONCLUSION

There are optimistic theories about development—about a great technological leap forward or about latecomers' ability to leapfrog generations of already outdated technologies. Yet, the digital divide will be with us for years to come, and the poor will remain in the worst position for a long time, even under the most ambitious programs. Yet, perhaps the greatest divide is between the *gains* we would all reap if all of us could use the potential of the new technologies to develop our talents in ways that could benefit us all, and the *willingness* of those of us who are in the rich parts of the world to enable, empower, and involve all those who are now poor, at the margins, and not connected.