5

STRUCTURING THE SCHOOL CONTINUUM

PLACE OF ICT IN SCHOOL LEARNING ACTIVITIES

In the *new school* described in the last chapter, computers are no longer placed in isolated rooms with locked doors to be opened only by an ICT teacher. Instead, subject-area teachers, administrators, and librarians all use them and other ICT equipment whenever these are needed in their working places. Ideally, the same is true for students. In and out of lessons, they use computers when needed: in classrooms, auditoria and labs, in the library, in rooms available for project activities and homework preparation. Sometimes students use smart keyboards for taking notes at a lecture, or palm computers when going out of school to conduct environmental projects. At other times, students use digital cameras. Computerized equipment is also used to monitor students' health. The entire school is immersed in the *information space*. Computers in teachers' and students' homes (school laptops and notebooks, shared by teachers, is one option) play an important role in the learning environment.

Limitations and opportunities

When administrators and decision-makers think about using computers in schools, the most obvious obstacle is cost of hardware. Actually, this is not the case! There are other real limitations existing in almost all schools today, discussed below in this chapter in the section *Barriers for ICT in schools*. Our goal first is to consider the physical structure of schools in space and time and to discover both the limitations and the opportunities inherent in this structure.

The nub of the problem is that few school buildings would be able to contain enough desktop computers for every student in every lesson. The problem then becomes how, in an existing school, we create conditions in which everybody in the school can use ICT when they need to.

Most schools in both developed and developing countries are over fifty years old. Some have existed for over a century. Classroom spaces were designed to reflect the traditional instructional style with little, if any, thought given to investigation-based, group learning, let alone fibre-optic cabling. While some funding is available for renovation and rebuilding, the short-term reality for most schools is that existing spaces must be adapted to accommodate new learning technologies. New or (re-)designed schools, and old schools, are thinking how to create more flexible space for ICT use. Traditional technologies like pen, paper, and blackboard will continue along with the newer ICT, which means leaving enough space on each student's desk for writing as well for a monitor.

Ownership issues

To whom does all this hardware belong? In planning school space, we need to address this problem as well. For equipment, we have alternatives:

1 Personal responsibility, which leads to better maintenance, less damage, longer life, but less access for the wider school population.

2 Collective responsibility, with the opposite consequences.

In the traditional approach, the computer lab is closed when the ICT teacher is not present. Do we have any alternative? Can we have a teacher present for part of the time, and for the rest of the time have a teacher's assistant or a non-technical person to keep order, or even a student on duty? Should the custodian hand out notebooks to students who sign them out, with the proviso (and an alarm circuit) that they only be used in school? In any case, special security rules and regulations should be issued and good habits formed in schools. When planning the information space, we need to plan well.

Typical arrangements of ICT in classrooms

Here is a list of options for space arrangements of people and ICT in a typical classroom:

- The whole class listening to one person presenting from the front, possibly through telecommunication (Lecture).

Equipment needed is a computer with a screen visible by the speaker, together with a projector and screen. To demonstrate an object, conduct an experiment, or show videotapes additional equipment is needed. To speak in a big auditorium a microphone is also needed. A projector is useful in other situations discussed below.

- Whole class discussion of a theme with questions asked and answered (Discussion).

  Equipment needed is the same as above, with a computer screen available for someone to take notes. To record the discussion, you need audio-video recording devices.

- Individual work by all students in a classroom (Essay writing, Testing, Studying new software).

  Equipment: individual computers (possibly, notebooks) at all student places; a school network is also needed in most cases.

- Pairing or grouping at one table (Experiment).

  Equipment: one computer for a group, with additional equipment (sensors and interfaces, microscopes, and digital cameras).

- Dividing the class into halves, with one each group doing individual work in an audio-visual environment (Language Lab).

  Equipment: one computer per student with headphones, microphones, a network, preferably a language lab environment with some sound reduction.

- Moving between zones (Technology or Arts Workshop, Project Activity)

  Equipment: a few computers, scanners, printers, plotters, devices controlled by computer.

- Individual work outside classroom (Homework, Distant Tutoring).

  Equipment: A computer with Internet connection.

- Group work inside and outside the classroom – in a local park, a supermarket, swimming pool, family house (Project).

  Equipment: palm computers and recording devices.

There are yet further options. Let us consider some of the possibilities available. We start with the most typical situation today of desktop computers in a classroom, and then consider more advanced options of portable computers and other places in school.

Desktop computers and computer furniture

Today, the desktop computer is the major ICT device in schools as well as generally in the world outside schools. School principals, ICT-coordinators, and teachers have to confront the problem of space design for desktops.

The space design of the computer-equipped classroom reflects three different models:

1. A teacher's computer with a projector (used by students also).
2. Several computers for group work in parallel with other activities (in primary school, language and science labs).
3. A dedicated computer lab that provides ICT access to all students, or, if this is not possible, to half a class at a time.

Information flow in the classroom

Let us start with the visual channel of information. In the traditional school, this channel was important for both the student and teacher. To the student, it allows:

- seeing teachers and images as they talk; and
- seeing a text in a textbook or workbook.

To the teacher, it allows:

- seeing the process of writing or conducting experiments by students, receiving non-verbal reaction from students; and
- preventing students from seeing what other students are doing in exams.

As we discuss above, ICT can influence this visual channel in a major way. In classroom planning, we should carefully consider the following questions:

- Are there obstacles standing between a student and the teacher and the projector screen?
- Can we reduce ambient light to improve visibility of the computer and projector screens?
- Can we use computers for the teacher to send visual messages to students and to monitor student activities?

Of course, in existing schools, the aural channel of information transfer is considered even more important (remember the teacher's remark "You are not listening John/Maria/Martel").

What solutions are available?

Imagine a typical classroom of about 8 meters by 5 meters with one computer and a projector. To make conditions comfortable for seeing the screen image for all students, the screen needs to be 1.5–2.0 meters wide and about 1–1.5 meters above the floor.

The class network can be used to monitor student activities. Teachers can see on their screen all student screens, or the individual screen of any student.

The teacher should control lighting and especially sunlight entering the room. Special window coverings and electrical lights section to be turned off during large screen presentation should be planned. During projection, the room light should be bright enough (40-50 foot candles) for student interaction, not just dim for note taking, but no more than 3-5 foot candles of ambient room light should fall on the screen. This can be done by creating lighting zones in the classroom, setting apart the student seating area, the front presentation area, and the lectern/projector area.

Computer noise should be as low as possible; others should not hear the sound emanating from any student's computer.

Desks and their arrangements

Desk space is designed and limited to a single student with a (paper) notebook and sometimes a book. There is frequently not enough space left for a desktop computer. The CPU can be placed under the table. This creates some inconveniences: for example, most of the computers' diskette and CD-ROM slots, power button, and interface sockets are located on the front panel of the CPU box, but some sockets are on the reverse side and it is hard (but amusing for students, of course) to manipulate all of these underneath the desk. With the hardware-software escalation noted in Chapter 2, we have monitors with larger CRT screens (namely 17”), but their placement in classes has become more difficult than it was for 14-15” ones. Of course, LCDs are thinner and so more convenient in school settings. Their prices are coming down, and perhaps they already are the better choice.

The keyboard should always be at hand, and it needs plenty of space. Nevertheless, the normal position for a keyboard is below the normal height of a desk. An optional flat drawer unrolling from the bottom side of the desk is therefore preferable.

It is important that communication and power lines do not interfere with physical movements in a classroom or auditorium. For example, a portable projector is a good idea, but you should be very careful where you place cables so that students do not stumble over them during lessons. In many cases, wiring becomes a major problem in ICT installation, taking up a good proportion of the costs. Although not absolutely necessary, raised flooring allows for easier reconfiguration of classrooms.

Traditional classroom layouts work especially well when the computer is integrated into the desk because wires and cables can be completely hidden, allowing narrower aisles while facilitating access to network interface and electric outlets.

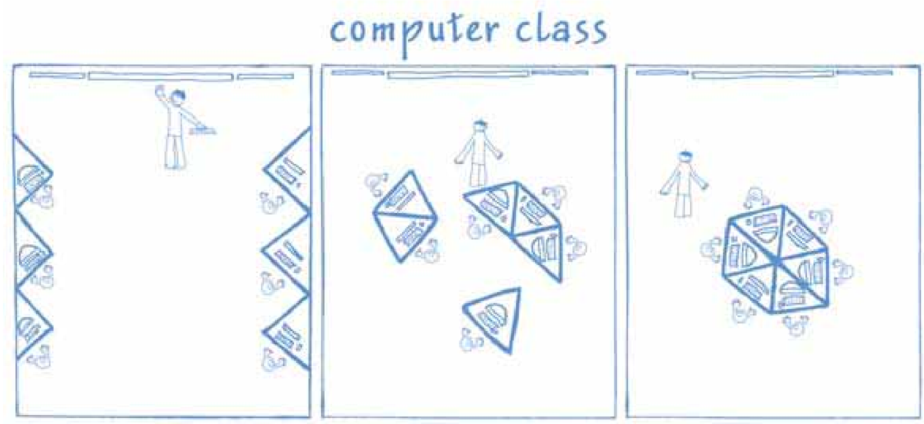
An interesting new design idea is to make the school desk triangular, which also helps solve the problem of changing the student’s object of vision from the computer to the teacher and back.

Desks in classrooms can be movable, to be reconfigured for different functions in the room. For example, individual triangular desks can be reorganized into hexagonal tables for group work.

Different layouts are used in classrooms oriented to the extensive use of computers:

- Rows
- “L” configurations

- "U" configurations
- Clusters of 4 desks
- Clusters of 6 desks



Computer chairs

Computer chairs that allow students to assume proper ergonomic postures should be selected. Students who spend many hours at a computer both at home and in the classroom run the same risks of cumulative trauma disorders as office workers, yet they have less control of the environments in which they work. Standard classroom chairs that do not meet these needs put students at risk.

Chairs need to possess the following attributes:

- height adjustability (preferably pneumatic). Ease of adjustment insures that students can achieve proper posture.
- back tilt. The facility to tilt a chair back is a useful feature that enables students to adjust eye-to-monitor distance within the space allowed.
- durability and tip resistance. Look for solid welds and heavy-duty mechanisms. A good test of tip resistance is to raise the chair to its highest position and hang a heavy jacket or book bag on the chair back.
- a broad seat and back design with adequate comfort with minimal sculpting. This design meets the needs of a large percentage of users. Although lumbar support and forward-tilt functions may be necessary in an office, it is more important to make users comfortable. Students usually present a greater range of body sizes than the office worker population.

Beyond desktops

There are alternatives to the familiar desktop computer, and here we consider some of these.

Portable computers (notebooks)

Some schools can afford to give students their own computer – one that is light-weight, small, and inexpensive, shock-, drop-, and water-proof and connected to a network in and outside school. Notebooks today:

- have full-functional operating systems;
- are more expensive than desktops;
- weigh about 3 kilograms, and can be damaged when dropped on a concrete floor; and
- are portable – you can use them in any lesson you need, not in the place where a computer is constantly mounted.

Schools should take the option of notebooks seriously. It is true that prices are nearly twice as high as for desktops. However, this is less serious a limitation in view of the costs of other hardware, networking, software, maintenance, and training.

Apart from cost, there are other discouraging factors for using notebooks that include:

- physical damage (by dropping or pouring liquid);
- thievery (of an easy movable and valuable object); and
- lack of personal responsibility (in the case of school ownership).

One solution could be to store computers on a cart or trolley that can be locked up at the end of the day. A notebook computer, printer, and LCD-projector on a trolley in a radio-network environment constitute a valuable combination in the case of limited resources. Of course, the level of interactivity and hands-on experience in this model is limited if you have only one trolley for a whole school.

Individual computers with limited power

Affordable alternatives to notebooks, discussed in *Major trends in ICT* in Chapter 2, are the following:

- smart keyboard;
- palm computers; and
- sub-notebooks.

A smart keyboard delivers the major text applications (text-editing spreadsheets, and email) and has a corresponding input device. They are functional in a school network or in association with a *real* computer. To reduce costs, internal memory, interfaces, and batteries are minimal. The result is still not cheap, because the product is not yet mass-produced. However, should a government decide to issue these to all schools in a country, prices are sure to fall substantially, to perhaps 10-20 per cent of a notebook.

Palm computers and sub-notebooks can provide interesting alternatives as well. Even today, these devices can provide certain critical applications like Internet connectivity for a small fraction of the cost of desktops.

At the same time, these and other *thin client* computers can all be made robust and unbreakable, they can be individualized, and they are less attractive to thieves.

There are two further affordable choices. The first was based on that early ICT classic – the calculator. Extended to being almost a computer, this tool is useful for mathematics, physics and ICT classes. A second emerging option is an ultra-portable projector about the size and weight of a camera that can be connected to a computer instead of its monitor. The price of these today is more than for a computer, but that is expected to come down.

Finally, in the near future we might expect wearable computers in schools. The computer here consists of a VR-helmet – output device and gloves – and a handheld input device. The computer is connected to the Internet, to other school computers, and to peripherals via a wireless network, or sometimes cables. Students will have these computers with them continually and use them in all lessons.

Distributed learning network in school

The school can be organized in such a way that the school's central information network is available in every room, which means an output device (monitor) and an input device (keyboard and mouse) with corresponding interfaces. There are also the options of stylus, finger (at touch screens), and joystick for Internet surfing.

In schools of the near future, we can imagine individual keyboards and helmets for all students, and many screens, mostly projection and flat-panel. The large projection screens in an auditorium will be used primarily with teacher or student presentations. Touch screens will be used for special occasions of choosing from a menu (including real school canteen menus).

The price for wired networking an entire school can be very high though costs can be reduced if some of the installation is done during school construction. Do not forget about power network and grounding. Wireless networks, infrared or radiofrequency in classrooms and in buildings, are less expensive than cable networks, and their reliability and information transfer rates are improving rapidly.

The presence of networked computers for out-of-class access in different places such as corridors, for instance, can be exploited productively in some schools, but may become tempting to vandals in other cases.

ICT everywhere in schools

As ICT become more pervasive, computer-based equipment will be integrated into every aspect of a school's operation.

Library and media centre

In most schools (at least of the European model), the library has for centuries been a place of less restricted, more individual, and more open work than a classroom. It has been the heart of our modern information civilization. In the last few decades, school libraries have begun to accommodate, not only books, magazines, newspapers, art creations, but also transparent media for projection, audio-cassettes, 16mm movies, then videos and CDs, and now, DVDs.

The natural expansion of the library's function is to provide ICT technology as well, including resources like high-speed Internet connection, satellite TV, collection of CDs and DVDs, plus a limited amount of paper for printing, and removable computer storage such as disks and flash cards.

However, there are problems connected with this most promising location. The first is space and number of available computer workstations. When librarians post up sign-up sheets, the usual finding is that:

- everyone shows up,
- if not, the reservation is cancelled and someone else comes instead,
- the timetable is fully booked weeks ahead, even with limits imposed of, say, an hour a day (three for teachers) with a maximum of three hours a week (6 for teachers).

This means that the technology is in demand. But what is happening with it? It is a good opportunity to ask users this question and provide priority access to those whose needs are greatest. Once you have data about usage, the next step is to apply for more ICT.

Computers for teachers

Let us come closer and look into a real classroom. Teachers are going to use multimedia projectors in lectures, which means they will also need:

- a computer as the source of video and audio signals;
- an extension cord to plug into the power line (assuming there is a socket in the class);
- a screen to project on (projecting on a wall can be poor quality; on a whiteboard, it can be even worse);
- a table to place a projector on;
- curtains on windows because sunlight interferes with projected images; and
- cables (most projectors today need sophisticated cables to provide an image both for the projector and for the monitor teachers are looking at so that they can stand or sit facing the class, though in the near future there will be more wireless connections).

Finally, imagine that a teacher has finished her lecture just as the bell rings. Students are running. Somebody trips on the cables... Fortunately, there are alternatives to such nightmares: ceiling-mounted projectors, wall-mounted electrical screens, wide-angle lenses, and light-dimmers. (Warning: if you turn the projector off before the fan inside stops, it can burn out.)

The arrival of even one computer in a classroom can have a profound effect on the way students learn and the way the classroom operates. Teachers integrating computers into the curriculum soon modify their class space to reflect the inevitable changes in student learning behaviour. Creating space in the classroom for computers and peripherals such as a printer, network connection, and large monitor initiates a rethinking process by the teacher, leading to re-evaluating how classroom activities and learning experiences work best.

Primary school

The model of a kindergarten or primary school classroom where children are involved in different, sometimes even unrelated, activities looks like gaining over the traditional school where all children sit in rows and are usually engaged on the same task. Computers (besides the computer-projector model) in quantities of one to ten can considerably enrich this multi-centre, multiple activities model. One of the possibilities here is to have a computer as a part, sometimes the centre of activity of a group of 3–7 students. Activities of different groups can be different or the same.

Foreign language lab

Another useful ICT installation in schools is the language lab. This has many of the features of the language lab that was popular before the computer era. The minimal model uses an audio source – a loudspeaker powered by a compact disk or magnetic tape player. A common problem is a different level of loudness for students who sit in different places in the classroom or who have other hearing problems. Individual headphones can solve this. The next step is to distribute the audio signal over an electronic network of students' headphones. We have now an opportunity for individualizing instruction but it brings an immediate problem of communication with the teacher.

The more sophisticated language lab gives individual audio and, then, video feeds to all students. Microphones are provided for students' feedback and recording, which can be monitored and checked by the teacher and individual learners (and, in an ICT environment by a computer speech-recognition system). To avoid disturbing others, students are placed into partly transparent, partly sound-absorbing carrels. These exist today, though they resemble our futuristic picture of students wearing VR-helmets. Indeed, language-lab helmets are already available.

In the language context, we recall that the computer can:

- integrate all types of information and communication;
- immerse students into virtual reality of another country and language;
- recognize human speech in some languages;
- supervize the learning process to a certain extent; and
- visualize and *audio-ize* for teachers the stage of progress of all students.

Language arts

The computerized classroom provides effective support for written and oral communication, and so it is desirable to have enough ICT for any language arts lesson. The typical problem here is the small number of computers per classroom. In fact, this is perhaps the major reason to look for portable computers with limited power (discussed above in this chapter).

Science lab

Specific applications of ICT in science learning are based on data collection and analyses done with sensors. A science lab can have, for example, six computers as part of a workshop for teamwork or individual data loading.

Palm computers (and, to some extent, data loggers) are more effective and provide greater flexibility with sensor applications in science investigations than do desktop computers. At the same time, at least one desktop computer is needed to run virtual experiments in virtual labs using other instruments.

Workshops of design, arts and crafts

Workshops and practice fit well with ICT. Therefore, in the arts and crafts class, workstations dedicated to specific activities can be designated. Students move from one activity to another at a different place in the classroom. Real-life projects are more natural and successful in these environments.

Music class

We discuss in previous chapters how ICT can help in music education. Let us repeat that the environment in music classes should support performance, recording, analysis and critical evaluation of the maximal variety of live voices, traditional and classical musical instruments and computer-designed music. The most universal peripheral here is a MIDI keyboard.

As in language labs, ICT must provide opportunities for individual work. Not all problems of ambient noise and interference with students' work can be solved with headphones.

Teachers' room

ICT in the teachers' room is an efficient way to support the information culture in schools and to invite more teachers to participate.

A teacher's workstation – a computerized system with a word processor, graphics editor, scanner, camera, modem, and printer – allows teachers to save time and to increase productivity in such activities as:

- preparing and updating daily lesson plans, making hard copy visualizations and handouts for classes, as well as individualized educational plans for slower students and students with disabilities or with special problems;
- presenting visual/aural content materials, tasks, and questions to the audience;
- maintaining grade books;
- compiling a data bank of exam questions;
- online inspection and correction of students' work on their computers; and
- keeping records, chronicles, and archives of all the above-mentioned events and proceedings with fast retrieval and easy access to any entry.

Dedicated computer lab

In most of the school computer labs of the 20th century, students learned how to use computers but were rarely asked to apply their skills outside the lab. We believe the situation in the 21st century will be different. The computer lab today is the space where:

- specific technologies are learned by students and teachers when needed in short modules;
- lessons in different subjects (testing, essay writing) can be given; and
- after-school projects and individual work with the use of whole variety of ICT are happening.

The advantages of using a lab are ease of planning and technical support. There is more responsibility, and so it is easier to achieve safety and maintenance requirements. In the computer-saturated school, there could still be reasons to keep the computer lab as the place of qualified support and the source of all types of ICT hardware and software for school needs.

Because there are rarely enough computers for all students in a class, a possible solution is for some students to work on computers while others work on non-computer activities related to the same project. This can require the collaborative work of two teachers. (See the *Two-teacher model* below.)

Virtual classrooms and open learning

In the future, more learning will occur outside school buildings. Creating virtual classrooms where students can log in and find course notes, resources, worksheets and teaching tips, enables students who are home-bound, out of school for sport or cultural activities, or on fieldtrips, to maintain contact with their coursework and teachers. This applies to non-traditional students as well as to older students, retirees, or those undergoing professional continuing education.

Many schools are pursuing this method of creating a virtual school, that is, an online community of students, staff and parents with Internet access at home or work. This networked community tears down classroom walls and enables teachers to utilize home computers to extend the school's capabilities. Online communications are enabled and students can work on projects from school or home. Students who are ill, or absent for other reasons, can maintain contact. This kind of networking also helps individualized learning. Virtual classrooms and virtual schools can be shared by different *real world* schools and supported from the outside. Today, you can find many virtual classrooms on the Internet. This concept of the virtual classroom leads us to the modern ICT interpretation of the idea and the term *open learning*.

School information space

There are other different places where ICT may be found in schools like the school principal's office and the custodian's room. We wish to emphasize that all these should be integrated: learning spaces of students, teaching spaces of teachers, and administrative space of school administration, are parts of a common school information space technically accessible to all participants of the educational process. The principal, looking for the administrative record of a student can move to her recent project work and send a message to her teacher.

Orphanages and other special schools

Orphanages, correctional schools, reformatories, and other types of educational institutions where children have limited access to the world beyond their walls are places where ICT can make a radical difference. ICT can provide a channel for free information flow, distance education, contact with peers from other, similar organizations and families, as well as with psychological help and support.

The same is true in a different sense for schools that might be special in different ways. For example, in schools for gifted children, contact with similar schools from other countries, as well as direct communication with the corresponding creative community provided by ICT, are important.

Implementing new goals of education in low-tech regions

In view of the swift progress in microelectronic technologies, it is remarkable that the basic computer environment has remained as stable as it has. The first Macintosh computer that introduced the multi-windows desktop and major applications about a quarter of a century ago had only 128K of memory and did not have a hard disk. Yet the screen metaphor of the desktop in which the user works now is the same as it was then.

What this means for schools is this: those with less powerful ICT or even none at all, can nevertheless develop new learning models that conform to the potential of ICT. In other words, schools can begin to teach a mastery of the new literacy before the full panoply of equipment arrives. The technology used can be quite simple – a camera with black and white film, a radio, a newspaper, an encyclopedia, pen and paper. For some countries it sounds historical, but for others this provides a practical way to a knowledge society through education. Sometimes, a chance to assemble or fix a transparent low-tech device can give more understanding of high-tech than applying an opaque high-tech device. One can even imagine a toy train, with its railway points and signal-posts, as a learning environment for hands-on learning of Boolean algebra and structural programming.

Equally useful would be asking first graders to collect the names, addresses and phone numbers of their classmates and create a sort of *Who's Who* to be copied and distributed to the class. The very experience of making oneself known to other people and getting the same message from them in return is a palpable metaphor for the World Wide Web. The impact of such an experience can be more meaningful than the short-time Internet connections of the uninitiated.

Another important issue worth noting in this context is that the fundamental science at the base of ICT was developed before the advent of computers. Its source was observation of information processing by humans. It has stayed essentially the same for at least 70 years and is now even more important. Therefore, this science is something that, independently of microelectronics, can and should be taught to prepare students for understanding information civilization and ICT irrespective of the level of computerization of their schools. Of course, this does not mean that ICT are not useful in schools, or are not useful for teaching computer science even.

We believe that real success can be achieved in education not only by affluent societies where a computer in every family is the norm, but also by those developing countries that respect and cherish their human potential and creative heritage. In the next chapter, we describe some approaches to teaching and learning computer science (informatics) that can be implemented with very different levels of technological support.

PLACE OF ICT IN CURRICULA

At every level of schooling, ICT are not a closed or self-contained subject to be taught and learned independently from other subjects. Rather, ICT are a subject that, by its very nature, should be treated as interdisciplinary, integrative, and cross-curricular. The project-oriented method of teaching and learning, introduced through the use of ICT, will help both teachers and students become more conscious of their own capacities and responsibilities.

Of course, some elements of ICT can be taught in a dedicated time. However, it is important to support learning by an immediate application of technology that is meaningful and relevant to students. In any case, introductory lessons in any specific aspect of ICT (constituting a module of learning) should not continue for more than a few hours (and, better, for just a lesson). However, even here, the task must make concrete sense for students right from the start.

The major module of intensive technical training is touch-typing, a skill for communicating between human beings and computers and which, naturally, needs fluency. Microworld-like environments allow children from the age of 3 upwards to learn and use ICT for usual applications (graphics and text editing), and for modelling the real world and multimedia implementation of virtual realities. The introduction to a microworld or any specific feature or application of it should not take more than few minutes before the first *action* of a child to achieve something.

Access to ICT

In planning their class schedules, different teachers should think about the information resources of the school and their access to them during their lessons. If the physical space of a school is seriously limited, the task of planning for ICT access is even more difficult.

Long-distance learning has its own special time structuring. Different options for synchronous and asynchronous learning are possible and supported by ICT.

Time when ICT are available

A common indicator of ICT development in schools is number of students per computer. However, another quantitative factor is even more relevant: the number of hours a week that computers are available for use. Of course, it is harder to optimize this parameter, than it is to put in a request for more hardware.

Nevertheless, we believe that any school can set as a goal to make ICT available to students and teachers 12 hours a day, 7 days a week. The implementation of this goal can also generate income for schools because this schedule would also allow the general public to come to school for ICT services when they are not being used by students and teachers.

PARTICIPANTS IN THE PROCESS OF CHANGE

In this section, we look at the process of change with regard to ICT from the early mainframe computers to the current individual workstations, and we examine the role of key participants in this change within school communities.

Early predictions

Back in the 1960s, it was proposed that the new rather bulky and expensive digital computing machines that occupied a whole room could perform, among other things, automated tutorial functions. The pedagogical community was startled and bewildered. Some excitedly predicted the decline, and even elimination, of the teaching profession by the onrushing Computer Based Programmable Education. Others were mesmerized by the sci-fi dreams of a huge artificial Super-Brain channelling a unified curriculum to terminals in every classroom. Still others envisioned direct electronic access to all data, information and expertise storage for anyone willing to get a private (self-) education. The established position of the teacher as a bearer of knowledge, mentor and preceptor was seriously questioned. A major project of the producer of giant computers, Control Data Corporation, was ambitiously called PLATO.

Barriers for ICT in schools

In the early years of the 21st century, personal computers, accompanied by peripheral devices, have been virtually declared obligatory for educational institutions in all economically developed (and many developing) countries. There is substantial evidence supporting the idea that the new information and communication technologies (that is, ICT) are already capable of bringing about spectacular positive change to the whole fabric of general education. The prospects for the foreseeable future are truly overwhelming.

At the same time, we should be extremely thoughtful and cautious in contemplating the exciting future. Schools and teachers face unprecedented pressure to get technology, get networked, and go online. At times, during this headlong rush to introduce new technologies, it is possible to forget what it is all for. To be sure, computers can raise student achievement in mathematics, languages, and other disciplines, but they have to be placed in the right hands and used in the right ways. The aim in the remaining part of this chapter is to paint a picture of what teachers and student roles might look like in an ICT-infused school.

The changes briefly sketched above have already occurred but only in a limited circle of pilot, magnet, experimental, and other especially selected exemplar schools. A popular view implies three main obstacles to the spread of these promising innovations:

1 the cost of ICT hardware, software and maintenance, although falling over the years, is still unaffordable to a majority of schools in many countries;

2 the (often unconscious) resistance of many educators to the intrusion of still obscure technological newcomers that threaten to alter drastically long-established and time-honoured practices and customs; and

3 the lack of teachers who are trained to exploit ICT proficiently.

Technology-rich curricula materials are therefore rarely implemented because students and teachers often have insufficient access to technology, and schools are unable to rearrange the curriculum to exploit the advantages of these materials.

Further reasons for slow progress to innovate are just as important as the obstacles just noted. These include:

- Low reliability. ICT hardware and software were initially designed and developed for non-educational purposes, and are thus poorly fitted physically for ordinary classrooms, especially in elementary schools. Available computers often do not work, which is aggravated by lack of maintenance support and inadequate software. This low and unreliable access to technology means that students do not get enough experience to master complex software tools, and teachers cannot assign tasks that assume ready computer availability.
- The rigid structure of the *classical* system of schooling (see *School as a social institution* in Chapter 3). Rooted in the educational paradigm of the 18th and 19th centuries, this kind of school could gain little from modern ICT unless it is radically transformed in its constitutive principles.

The last point is perhaps the most crucial. In fact, most educators are not ICT-resistant, but the system in which they work under undoubtedly is. Technology (information or any other) brings little benefit unless it is skillfully and thoughtfully conducted and managed by teachers to enhance students' capacity to learn. Never before has the mission of schoolteachers been so heavily loaded as today.

Taking account of all the problems of transforming schools, we consider now the changes in the roles of the key participants in the educational process.

Students

With the need for more independence, creativity, as well as the ability to engage in teamwork, the role of the individual in society is becoming more and more important. Today, it is natural to wish to design a school that is oriented towards developing these attributes, which can be done for all age groups, based on ICT.

Modelling the world beyond school

One of the natural features of learning by doing that is facilitated by ICT is the similarity between the educational activity of a student and the activity of an adult at work. Student-journalists and student-researchers, for example, can produce significant results, even if they are only eight years old. Similarly, middle school students (12 to 16 years old) can provide technical service, expertise and consulting in regard to ICT. Students can participate in choosing equipment and software, its installation, repair, and even the technical training of teachers. They can also participate in lessons as technical support experts. Teamwork and working with younger children provide many possibilities.

By using the computer as an environment, a tool, and an agent, to design, create, and explore model worlds, students get unprecedented opportunities to see, analyze, and reflect on every step of their own learning processes, thus acquiring mastery, not only of the subject matter, but also in the art of learning.

Collaboration and teamwork

The social climate in many academic settings is often fraught with competition and isolation. Where collaborative and cooperative learning opportunities are increased, achievement scores are known to rise, and students respect the contribution that each person offers, regardless of differences in ability, background, or handicap. Instead of fearing differences in one another, they look for ways to tap the unique and individual areas of strength for the benefit of all.

A collaborative approach paves the way for a radical re-shaping of the content and procedures of the general school curriculum. Practical implementation of these kinds of transformation become possible when supported by advanced ICT to create powerful learning environments.

Teachers

Teachers of ICT

ICT can and should be an integral part of most learning activities, and as available as pen and paper. Meanwhile, in many schools today, and probably for a time into the future, the only teachers with everyday access to ICT are teachers of a special subject called Information Technology, or Computer Science, or Informatics. These teachers can carry the important mission of being agents of change, not only in ICT, but also in the whole system of education since ICT are the instruments that can launch an important and general paradigm shift.

As was indicated above in the section, *Place of ICT in curricula*, we can imagine a combination of ICT with other (material) technologies. In this case, one teacher might naturally blend several technologies as a productive starting point for the integration of ICT into all learning activities. In fact, it is often the case that teachers of material technology, who start simply with an idea of applying technologies for human needs, make better, more creative use of ICT than teachers who start with the conception of the value of ICT (or programming) by themselves, but cannot necessarily see their possible uses in solving human problems.

Master teachers

The master teacher is one capable not only of instructing but also of constructing a role model for students. Master teachers look for ways to construct learning experiences that are both interesting and appealing to students, something that might provoke and inspire them to attempt to construct something similar by themselves in the hope of reaching the mastery and artistry of teachers, and, perhaps challenging them in the future.

Teacher support

In the everyday use of technology, teachers need to be able to get fast and reliable technical advice and have the help of suppliers of technology, technology resource centres, and other teachers and students within the school.

Special kinds of educational support are even more important because they affect the new model of teaching. Such support can be provided both personally and online by a special member of the school staff, by a technology resource centre or university, or by members of the community of teachers using ICT.

Different kinds of administrative support are also needed, including an opportunity to participate in ICT events, to buy supplies and use telecommunications, to upgrade technology, and to publicize and promote teachers.

The presence of enthusiastic teachers, together with the installation of hardware and software, add little if support is not present. The introduction of ICT requires establishing and coordinating an entire infrastructure of support. This infrastructure should be multifunctional and include:

- technical support,
- organizational support,
- being educational and multilayered,
- being present in the school,
- being present in teachers' and students' homes,
- being present in local resource centres and teacher clubs,
- universities,
- technology providers,
- national clearing houses, R&D institutions,
- international communities and organizations.

Teacher support can involve face-to-face and distance interaction, and all types of workshops and publications (including user groups and bulletin boards). The merging of government, foundations, non-governmental organizations, and informal grassroot efforts is the most effective strategy.

Technology coordinator and pedagogical advisor

Many secondary and even elementary schools today have a computer (or ICT) teacher, and an increasing number of elementary schools also have a person who supervizes the computer labs (classrooms equipped with computers). In some cases, this person is a certified teacher. In other cases, the lab supervisor is considered a technical support person and may not be a certified teacher. The Technology Coordinator position was proposed in the late 1980s to designate an educator at the school or district level who works to facilitate, assist, and consult on the effective use of a wide range of computer-based and digital-related ICT in teaching and learning. This person may also have duties as a non-ICT classroom teacher or as an ICT teacher proper.

Another person who can be useful in introducing ICT is a pedagogical advisor (e.g. another teacher), who can help with relevant lessons and in their preparation. In this case, the elementary school teacher learns hands-on how to use technology in new ways of teaching. With adequate financial support, this can be done on a regular basis, formalizing the two-teacher model.

The role of advisor with this responsibility can be held by a technology teacher, a subject-area teacher, a member of a technology resource centre or in-service support institution, university professors and students, or even by a student from the same school. Out of these experiences, general categories of participants can be discerned who support and promote ICT usage in school:

- The ICT-using, ICT-literate educator. Library media specialists fall into this category.
- The ICT teacher. This person may teach computer applications, hypermedia literacy, programming languages, and computer science to both students and teachers, taking part in group work with other teachers and in interdisciplinary projects.
- The technology coordinator.
- The pedagogical adviser.
- Certain students.

Two-teacher model and teamwork

An effective way to present technology lessons involves two teachers with different, complementary expertise: a regular teacher and the technology teacher. The two can work together in lessons where ICT are applied for a specific task. In such cases, both teachers become involved in mutual learning, which leads eventually toward an integrated curriculum. As a result, technology teachers help their colleagues bring high-tech tools deep into the fabric of *traditional* instruction (and provide, if necessary, on-the-spot troubleshooting). This, in turn, enriches the technology teacher's own understanding of related topics from different subjects. Elementary school teachers learn ICT along with their students; technology teachers learn important needs and applications for ICT and disseminate them further. This two-teacher relationship is really a microcosm of a learning school.

To make this model work on a wider scale, we need administrators who will permit the co-operative work of two (sometimes, even more) teachers in one classroom (generally with half of the class only) and, of course, with equal financial remuneration. The legalization of this option by authorities will make a big direct material impact and, even more importantly, a psychological shift in the consciousness of teachers and administrators (and the families of teachers and the community).

Possible team partners for the elementary school teacher include teachers from other schools, parents, and volunteers. Of course, there are teachers who work alone, and many successful examples of that kind exist.

Other stakeholders

Besides students, teachers, parents, and the community, there are other participants who play a critical role in the process of change: school administrators and higher education authorities.

School administrators

School administrators are more accepting of ICT in a school, when they use it themselves. Therefore, provision should be made for this. Moreover, information space of school management should be integrated with learning and teaching space. Information space should be accessible via telecommunication channels to students, teachers, administrators, parents and other members of the local community. Of course, there should be limitations on access and authority to change information.

Educational authorities

A school's ability to use ICT is based on the ability of its teachers. At the same time, most decisions are made at a higher level of administration, where money is allocated for school needs. Naturally, some decisions regarding the educational paradigm and general strategy are made at the national level.

The government that makes decisions on national or regional standards can support the introduction of ICT-based goals, targets, and standards in schools. Obviously, this cannot be done simultaneously and with the same depth in all schools (see *Zone of proximal development* below). However, the enthusiasm engendered among educators on receiving technology can be used to develop a vocal constituency for the broad introduction of technologies into the educational practice of these schools. Even in schools that are generally not enthusiastic and engaged in technology, a teacher or a student will be given a chance to become a catalyst for future change.

Educational authorities can combine approaches in formulating content and methods for an ICT agenda within a school system, region, or country. These include:

- Explicit formulation of new priorities and new models of learning in standards and objectives of education – a key factor in the process of introducing ICT. Some of these standards may refer directly to ICT while others may not.
- Inclusion of elements of the application of ICT into curriculum guidelines of different subjects.
- Introduction of courses on technology or ICT in which priority is given to new goals for education and applications of ICT in integrative projects with other subjects.

Educational authorities should provide quality software and educational support, which can be done on the basis of licensing for a region. Authorities can decide to concentrate support on a special project that is interesting to several schools, or on a system of projects.

Parents and the community

There is an obvious need for ICT in family and home education where they can provide the major media, content, and human communication options. Distance education (in and out of school) in elementary and secondary schools also needs human (teacher, parent) participation in close contact with the learner. Parents should recognize the need to build new levels of relationship with their children and should consider the computer as a vehicle for building, rather than an obstacle to, family cohesion, and, finally, the family's learning culture. In some cases, parents constitute an important force in support of ICT in school.

Clubs and community centres provide access to ICT for many young learners, especially in communities where an individual computer is a luxury. For socially disadvantaged children, who often are not involved in formal education, such clubs provide an opportunity to be integrated into society.

Resource centres and qualified personnel who work at several schools in a locality can be effective at certain stages of introducing ICT into education.

Schools part of wider learning communities

One of the main functions of schools is to provide an environment in which students can design and construct any number of physical and virtual worlds with which to interact and accumulate direct learning experience. This learning by doing links the mind and body and facilitates knowing, remembering, and the practical implementation of what is learned.

Connecting with the outside world

Any learning environment of the kind described immediately above must have varied connections to the world outside the classroom, including manipulative and construction kits that model the universe, society, and technology, observations of nature, and productive activities. These connections should extend to consulting with eminent scientists, engineers and artists, and inviting local political figures and entrepreneurs for roundtable talks, and to project planning with the students.

Zone of proximal development

The richly connected school of the future can be described by using the Vygotskian metaphor of *zone of proximal development*. The zone of a school consists of areas in which the school (represented by its teachers and the whole learning environment) is ready and eager to move forward – in our case, in using ICT. The zone also reflects the position of the school in the community of other schools. For example, a school has an IT-teacher who is discussing with a science teacher an opportunity to implement an environmental project connected with information that appeared in a local TV-broadcast and newspapers. They are optimistic about the reality of their plan because they have seen a similar project at a recent technology in education conference. They approach the principal who is supportive and mentions that another school in the same town is very strong in technology in science. The two teachers therefore come to the second school; they are inspired by the science teacher there and find out that they will need something called *sensors* and *palm computers*. They come to their state university for a summer course and negotiate leasing these sensors, partly from the university, partly from the second school… This entire story represents a move of the school in its zone of proximal development.

Determining the zone of proximal development is based on:

- achieved results;
- technical skills of teachers and students;
- project activity of the chosen schools;
- individual planning of all aspects of new technology introduction, including hardware configuration, curriculum and timetable changes, administrative applications; and
- development of communities of teachers and schools, including Internet user groups, clubs, seminars, publications, connecting with international communities, sources of information, scientists and other people who can provide first-hand information for school activities.

For the purpose of money allocation (region or municipal), decision-makers can use the model of the zone of proximal development and collect proposals from schools and impose qualification requirements. The simplest requirement for receiving ICT equipment is for schools to have an ICT-based curriculum, specified teachers, and a two- to three-year plan for the use of ICT for a given fraction of all lessons. They may also plan other aspects such as sources of teacher support. In this case, competition among schools usually turns out to be minimal. This procedure should be supported by follow-up plans.

No one model for all

The perspective outlined in this handbook – seeking changes in society, ICT, and education – is not the only model of development. We acknowledge that there are countries and communities with different sets of values, which give priority, for example, to tradition, discipline, uniformity, collectivism, and state control.

Nevertheless, ICT and education can support this set of priorities as well as others. It can even support and reinforce the teaching-learning process in traditional systems with new tools of visualization, presentation, and automatic test control of results. At the same time, we observe that the most productive use of ICT enables and requires a transformation of the traditional model of education.

Drawbacks of ICT

Besides the undoubted advantages of ICT, it is rather important to draw attention to certain drawbacks of ICT.

Computer games

Part of the attractiveness of computer games is based on having a feeling of control over a quasi-reality, being in the thick of the action, and the ability to raise self-esteem by achieving goals, power and success in the through-the-screen world (a desire to win, or win back), and a curiosity about the unknown. If something goes wrong, the person in control tries to fix it. In the worst case, this fixing is chaotic and essentially irrational. In that aspect, computer games are similar to other types of hazard games or stock market games. Another dimension of their attractiveness can be associated with purely psycho-physiological mechanisms and a reflexive physiological adrenalin reaction to moving images.

Some of this excitement takes place when one is getting accustomed to new software applications, or while creating programs (especially by hackers). Some programmers may perceive the world and events they are working with in an entirely irrational manner. The process of winning a game, or debugging the program they create, may depend on the positions of planets or some ritual actions of men! Loss of orientation and the destructive behaviour of a hacker are other negative consequences of ICT use. However, it would be unjust to blame computer-driven information culture for all negative phenomena of contemporary life connected with ICT. The cure for these problems lies not inside ICT themselves, but in building a solid moral orientation for youth in how they use this new information sphere. In other words, we must give them a good upbringing.

Unlimited access to information

The advent of ICT has encouraged, in some quarters, a more passive consumption of information, primarily in visual form, which is analogous to the passivity of TV-viewing. We have the mass production of low-quality texts, which are consumed in huge amounts. The Internet gives uncontrolled opportunities to publish and more uncontrolled access to such publications. Moreover, it gives children access to pornography and drugs, as well as to child abusers posing as e-pals.

How is society to deal with a young generation that spends so much time watching TV or reading tabloids, and now surfs sleazy websites? What has been done up to now? The answers some offer are not too encouraging. Restrictions have been proposed and introduced, both in families and educational institutions. For example, there are schools where computers do not have floppy-disk drives to prevent students from downloading games (and viruses). There are special Internet services, which, if you subscribe to them, will restrict students' access to dangerous and controversial sites on the Web.

However, these restrictions are really efficient only if students are brought up in an atmosphere of free cultural choice and are encouraged to say *no*, that is to refuse something of their own accord. Therefore, the answer we expect is the same as in other cases like drugs, for instance: a combination of technological restrictive monitoring, and controlling solutions with morals, tradition, and culture.

Losing traditional skills

We sometimes hear that students using computers are less proficient in arithmetic than their friends from non-computerized classrooms, or students of the pre-computer epoch (their parents). These statements have some truth to them. But it is also true that if we offer an arithmetic problem to an average adult while depriving them of a pocket calculator, they would manage this task worse than ordinary people did fifty years ago. We believe a change of priorities in life should influence a change of priorities in education. If one agrees with this, it means not only adding new priorities but also losing certain old ones.

It is perfectly clear that doing arithmetic mentally or on paper was more important in the 19th century than today. Everyone who now does calculations professionally uses a calculator. Many people use calculators while shopping in supermarkets or conducting business negotiations, and especially for calculating tax returns. If you do not use a calculator in a restaurant or supermarket, you will need the ability to add many small numbers and to estimate, not the ability to add or multiply two long numbers. Adroitness in quick and reliable quantitative approximation is more important than the capacity to make pencil-and-paper calculations slowly.

The educational consequence of this shift is for less traditional arithmetic in the classroom. If we compare the problem-solving ability of the traditionally taught student with a student who has been taught new literacy and is equipped with a calculator or computer, we would not expect the latter to achieve worse results. Another argument for traditional school arithmetic is that it develops certain more general skills such as logical thinking, or that it constitutes the basis for learning higher mathematics, which is important in its own right. However, this argument is not obvious and, perhaps, not even true. It is quite possible to organize learning mathematics in a more effective way, both for the general development of the student, and for the priorities of the new information environment.

We meet the same situation with handwriting, spell-checking, and memorizing facts. The old priorities are losing their importance. Is the new literacy good enough for the emerging world? We believe that the answer is unquestionably *yes*.

Health problems

Health problems are discussed in Chapter 2 under *Health problems associated with computers*. In the first stages of introducing computers into education, some parents and educational communities were concerned with the effects of monitor radiation and eyestrain. At present, most countries do not have special regulations that limit access to ICT for students for health reasons. We think that more research and investigation should be done at an international level and the results widely distributed, possibly through channels like UNESCO.

In addition to the health factors discussed in Chapter 2, we should consider such factors as comfortable lighting and furniture. At the same time, we can explore regulating students' activity, for example, by introducing physical exercises during computer lessons.

6

MATHEMATICAL FUNDAMENTALS OF INFORMATION SCIENCE

MAJOR COMPONENTS OF INFORMATICS IN EDUCATION

In this chapter we use the term *informatics* as unifying computer or information science and technology, as the term is used in some European countries.

We see informatics in education as having three interrelated aspects:

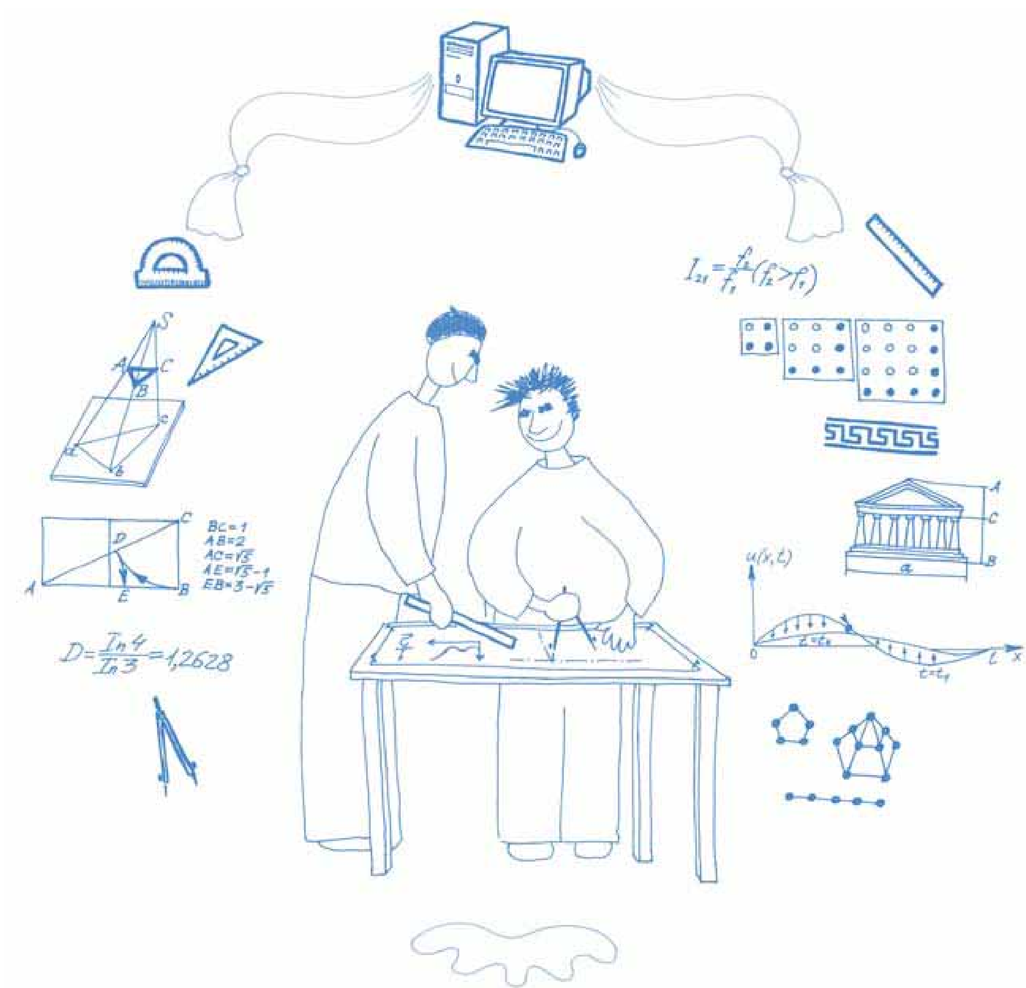
1 Fundamental, theoretical informatics.

2 ICT and issues in science and other fields of human culture related to ICT (including economics, ethics, ecology, aesthetics, arts, philosophy, and history).

3 Use of ICT in educational activities.

It is widely accepted that mastering ICT, like other subjects of study, is accomplished most effectively in a framework of activities that are relevant to students. Most of the important areas of the application of ICT and theoretical informatics are covered by this approach, and this is the major theme of the discussion in this chapter.

It is convenient to discuss the second component of informatics in education above first. Therefore, in the next section, *World of information*, we outline



the content of ICT applications to be learned in school as part of what throughout this handbook we refer to as the *new literacy* (and we separate it from the context of the subjects where it is taught). Next, in the section titled *Fundamentals of Informatics*, we explain briefly the first component of informatics in education above by detailing the content of informatics in its mathematical form. The discussion of the third component – the use of ICT in educational activities – is, of course, the major content of the whole book.

WORLD OF INFORMATION

The main content in learning informatics in school focuses around ICT. But there are many reasons to cover information processing in technological, biological and social systems, and their implications for our life as well. Therefore, in this section we discuss in a unified way, first, information objects; next, information processing by humans equipped with ICT; and, third, the information process in a broader context.

Information objects

Let us start with recollecting certain facts about information, which are touched on in the first section of Chapter 2. An empirical classification of information objects starts with a distinction between objects we perceive as a whole homogeneous entity and information objects where we perceive an inner structure as its fixed and permanent part.

The classification below into simple and complex information objects does not pretend any philosophical depth or completeness. It simply helps to classify information-processing activities that are elaborated in the following sections.

Simple Information Objects	Complex Information Objects
• number • text • image • sound • moving picture • three-dimensional object (considered as message)	• database • spreadsheet table • hyperobject (or hypermedia object) or combinations of the above

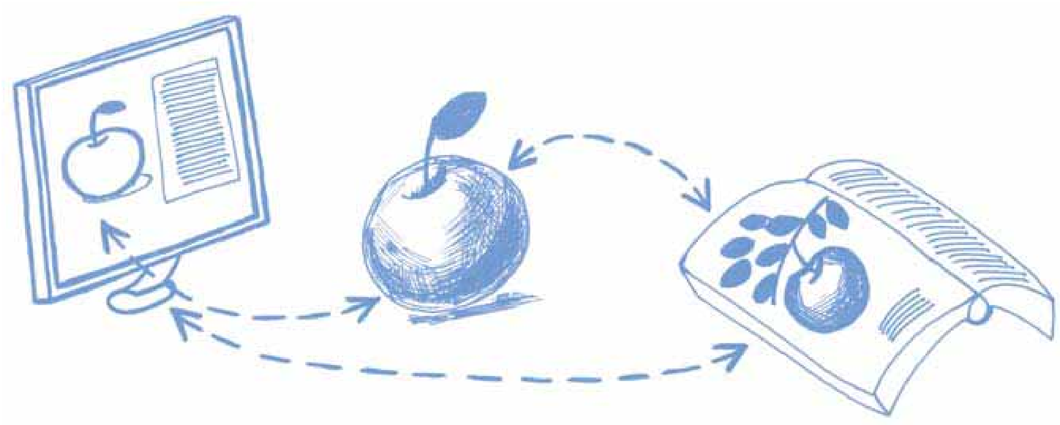
Integration of all kinds of information

At the beginning of the computer era, computers were mostly used for computation. Later, computers began to be used for text processing, and this continues to be the most popular application today. Texts, as well as sounds, images, and video can be presented in a unified way as sequences of zeros and ones. The important fact is that digitized images, sounds, texts, and numerical data can be processed with the same devices (computers), stored in the same magnetic, optical or other type of storage, and transmitted via the same telephone lines, optical fibres, or satellite radio channels. One and the same computer today can play the role of answering machine, fax, phone, TV receiver, or movie screen.

Hyperstructures of information

In many cases (for example, in oral speech, movies, and printed media), pieces of information are organized in a linear, sequential way, one phrase, episode, page, or encyclopedia entry, after another. At the same time, human memory and thought are organized in an essentially non-consecutive (non-linear) *connectionist* manner.

In some cases, people overcome this contradiction by placing information objects on a diagram with arrows and connections, or make references or links, or provide footnotes for the interested reader. Words marked, for example, in italics in an encyclopedia article link to related articles They also structure text by introducing chapters and paragraphs.



When we access information on a computer, we can go from a reference in one article to another article (even to a different book) in a split-second. Moreover, the reference can go to a different computer – even to a different continent – perhaps not in a split-second at present, but quite quickly.

This kind of so-called hypertext structure, which is technically easy to deal with, covers pre-computer reference structures and corresponds naturally to human thinking. All possibly relevant connections can be made, enabling anyone to make associations, establish logical relations, and create multilayered networks of meaning in accordance with individual thinking patterns.

When we extend this idea to other types of information – from text to images, video, and sound, for example – we get hypermedia objects, or hyperobjects, which connect together, not only various sources, but also different modes of information. The reference may thus take a reader from a graphic map to a sound file.

Information activities

Let us return to the list of information objects and see what people do with them. All learners, even the quite young, deal with information objects in several different ways. They:

- create: write, draw, pronounce, and build;
- search and find, retrieve, discriminate and choose: Internet surfing is the most popular and most controversial example; listening, reading, browsing in libraries, and watching TV are activities of the same type;
- fix or record an information object as a representation of reality: photograph with an ordinary or digital camera, record an interview or ask people to fill a form, measure temperature;
- process and modify: edit text, video, images;
- analyze: divide into parts or elements, compare, look for patterns;
- organize, present in a different form: compile or edit a hyperstructure from pieces of information, create a spreadsheet, a slideshow, visualize numerical data;
- communicate to others (e.g., make a screen presentation, post to an Internet site).

Learners also simulate, design, and control the following objects and processes:

- technological: material, energy, information processing; and
- human, including management of their own projects and planning activities, as well as information activities: divide and join tasks and labour; choose objects to record, photograph, draw; decide what to measure and how; construct plans for interviews.

The above list can be expanded, as is done below where we describe scenarios and projects of learning.

We stress that, in the school of the future, general ability in information processing will be among the important results of education, from memorizing facts to critical thinking, social management, and scientific research, using ICT as instruments.

There are important topics concerning social aspects of information activities of people such as copyright and privacy, the knowledge economy, and ICT in professions. We believe that all these topics should be covered in the proper time and place but best of all be based on personal experience, observations, and investigations of students themselves.

Understanding information processes

In the early days of computer use in schools, it was considered important to learn how computers work. Today, we realize that it is not necessary to have a background understanding of electronics and programming to use computers productively. At the same time, there are several reasons to include this kind of understanding in primary and secondary education.

The first reason is straightforward and pragmatic. You can apply ICT more effectively if you know how it works. For example, it is useful to know that you need electricity to power a computer, that computers talk to printers via this cable or that infrared channel, and so forth. One of the issues in this topic concerns quantitative estimates in ICT. Occasionally, it is helpful to know how many bytes a particular text being digitized will occupy, how many minutes of a compressed video will fit into available computer memory, how long it takes to transfer a picture via the Internet, and so on.

The second reason is that ICT provide a rich set of examples and applications for the mathematics of informatics. As might be expected, understanding the essence and inner logic of technology plays an important role in the effective use and coordination of its different applications.

Finally, there is a general and philosophical reason for including an understanding of information processes in the curriculum of primary and secondary schools. It helps students to develop an ability to conceptualize more broadly in various disciplines, and in life itself.

Forerunners and founders of informatics

A formal treatment of human reasoning began at least in Ancient Greece. Since the end of the 19th century, mathematicians and philosophers started the development of the mathematics of formal reasoning. In the 1930s, this development reached a peak in mathematics with Goedel's results on the completeness and incompleteness of formal reasoning, and with the work of Goedel, Post and Turing on completeness (universality) and incompleteness (noncomputability) of formal acting. In the 1940s, advances in electrical and later electronic engineering, as well as the demands of the military, led to the construction of the first automated calculators.

Universal computers were developed around 1950. Mathematical science was ready for this. As one example, the well-known Russian mathematician, Andrei Markov, published a complete symbolic code for a high-level language compiler accompanied by a complete formal proof of its correctness in 1947, in a several hundred-page volume. Mathematicians were also involved in the design and construction of the first computers (John von Neumann) and in their first applications (Alan Turing). In the late 1940s, Wiener coined the term *cybernetics*.

FUNDAMENTALS OF INFORMATICS

Here we use the term *mathematics of informatics* or *mathematical informatics* (just like mathematical physics or mathematical biology) to describe the area of mathematics used in informatics, and the area of applied mathematics working with models of objects and processes from this or that field. This complex of pure and applied mathematics produces definitions, constructions, and theorems applicable to information processing by humans, living organisms, social and technical systems.

The notions and concepts of mathematical informatics are as simple and fundamental as integer numbers. These concepts can be viewed as the natural basis for mathematics dealing with finite (computational) objects and, using the abstraction of actual infinity, for all mathematics. Today, it is clear that the basics of mathematical informatics can be included in the primary curriculum.

The content of mathematics of informatics and its applications for primary school may be different in some educational communities with different traditions of teaching mathematics and primary teaching in general. Applications and examples can differ more than the fundamentals. At the same time, an analysis of approaches taken by educators shows that, as in other fields of mathematics, there is much that is common and universal in the content of the mathematical basics for informatics.

Here is one possible way to introduce computer mathematics into elementary school. We start with basic notions, not trying to give them an exact definition – neither logically nor philosophically correct – but instead describing them in intuitive terms. These notions are introduced to students in the form of visual (graphical) and palpable (manipulative) examples. In that way, a general (non-verbalized) understanding arises in a student's head due to the inherent mechanics of cognition through direct perception and acting.

Major concepts of mathematics of informatics

Beads

The simplest objects are *beads*. These can be made out of wood, but more often they are drawn or printed on paper. Beads are of several forms (circle, square, and triangle) and colours (red, green, blue, yellow, black, and white). So, they have attributes, or properties. Letters of alphabets and other symbols are beads as well.

Strings

A *string* is a sequence of beads. There are first, second, third … and last beads in any string.

Other examples of strings are a string of letters in a word, a string of words in a phrase, a string of phrases in a tale, or a string of events described by a tale. A general source of examples is the one-dimensional timeline and the human wish to structure it by distinguishing specific moments or solid intervals.

Bags

Bags are another type of complex object. In constructing a bag, we take selected objects together. Thus, there is no order between them and we can take several identical objects. Bags are also called multisets.

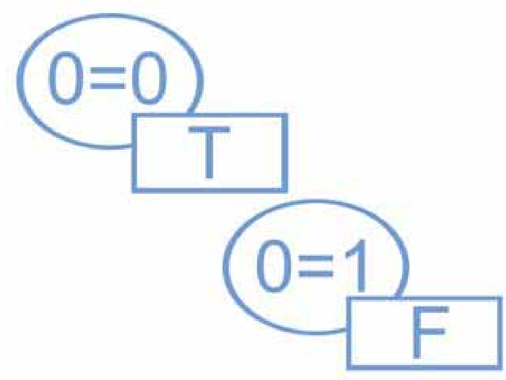
Names

Objects are given *names*; an object is the value of its name. We can use single letters as names; and names can have complex structure as well.

Truth values

Some natural language texts (strings of letters) have True, False, and Unknown as their *values*. Some texts do not have value.

More complex objects



We can make strings and bags out of strings and bags. For example, we can produce a bag of strings, or a string of bags, as well as bags of bags and strings of strings. Trees (in which the sequence of objects or events is branching) are also introduced as a class of objects. Of course, trees can be represented or coded by other objects (for example, bags of bags of bags), but the graphical representation is important for us. Trees reflect structures of classification, some linguistic structures, and structures of reference. Arbitrary graphs have a proper place. One-dimensional tables correspond to mathematical functions, and two-dimensional tables to operations. They are used also in many applications.

It is important that all types of objects have clear palpable and visual implementations.

Operations

Operations over strings and bags are introduced. We can concatenate strings in a string. Or, we can add together bags from a bag of bags. In this last case, we can also define union (maximum) and intersection (minimum) of a bag of bags. We can also concatenate a string of bags of strings to make a bag of strings. To concatenate a string of two bags, for example, we consider all possible concatenations of strings from the first and from the second bags. The last situation reflects multiplication of polynomials.

In the context of action (as in programming languages), strings correspond to sequential actions, and bags to sets of options or possibilities. There are also relations (predicates) over our objects. The simplest relation is being the same (identity). This relation is intuitively clear and can be introduced by graphical and material examples. There are other relations such as inclusion for bags, and succession of beads in a given string.

Logical connectives

Let us have a bag of statements. It is clear what it means when we say “All statements in this bag are true“. Now, the meaning of the statement “This statement is true for all objects in that bag” is clear as well. Similarly, we introduce constructions of existence (“there is” or “there exists”). Negation (“This statement is not true”) is introduced with caution as in some cases it is harder to comprehend.

Processes

Processes we are interested in are described as strings of states. Each state is an object (in our sense). Playing a game is an example of process. Trees and other graphs are used to describe possible runs of processes. Winning a game and winning strategy concepts are introduced in a general way. Analyzing a logical statement can be understood as constructing a strategy. Probability notions appear in practical examples and games.

Programs

The primitive components of *programs*, instructions, have as their meaning actions (operations) on states. In the construction of programs, operators as composition (subsequent execution), branching, and iteration are used. Variables are introduced first in the simplest form of global variables. Systems of functional equations defining a computable function are considered. Parallel processing, non-determinism, and probability also have their place.

Languages

We use the names of objects, operations, logical connectives, (program) operators, and other tools mentioned above to construct complex names. Parentheses (brackets) are the key instrument in such construction. Variables for objects and operations are introduced.

Machines

To describe program execution more clearly, abstract *machines* are introduced.

Specific approaches to program design (division of labour, top-down analysis, raising reliability of probabilistic computations) and practical algorithms (sorting, exhaustive search) are introduced (again, in visual and palpable contexts).

Needs in (semi-) formal proofs appear in analysis of games and of program execution (correctness proofs). Non-existence proofs by exhaustive search and diagonal construction are discovered.

The critically important component of the learning process is wide applications of major concepts, which include models of natural language, real games, searching in information sources, and individual and group design of meaningful software. These are considered in the next section.

Environments and applications

An understanding and ability to use the basic concepts of mathematical informatics can, and we believe must, be achieved in environments where computers do not play the leading role. To a large extent, we feel that computers can be absent altogether. For elementary school children, definitions can be presented through visual, tangible or kinaesthetic examples. We list here a few of these environments, as found in different educational communities around the world.

Sequential time and speech

Text originated from oral speech. Naturally, it is one-dimensional – as a record of sounds evolving in time. We represent text graphically, and on the screen, as a sequence (string) of symbols. It is convenient to arrange such sequences two-dimensionally on a sheet of paper, or on a computer screen as lines of text. The one-dimensional essence of text, however, is reflected in the operations one can conduct on it with a computer. You can, for instance, select any sequential (one-dimensional) part of the text, cut it, and insert it into any place in the text.

Therefore, our concept of string reflects human speech as well as human reflection on sequence of events and the physical one-dimensional time.

Non-ordered space and choice

We can see, or imagine, a collection of objects simultaneously and non-ordered. A possible next event, or action can be represented by that kind of collection as well. Sometimes a collection appears when we want to distinguish between some objects and everything outside. Such collections can contain many identical objects (like molecules in gas), or similar objects that we treat as identical. You can represent this situation in graphical form as a bag (an oval), inside which objects like symbols, strings, or other bags are placed.

Our concept of a bag thus reflects the physical world of objects and our human perception of it as well as opportunities of choice and combinations of objects.

Natural languages

Every human being has the ability to manipulate linguistic objects, to create new ones, to wonder and experiment in linguistic reality. At the same time, major constructions of languages of mathematics and informatics are based on natural languages. Consequently, reality of linguistic objects constitutes an important environment for learning informatics. Objects, regularities, and peculiarities of languages can be described and discovered by means of mathematical informatics.

Artificial formalized languages

The languages of algebra, logic, programming, interaction and games, and different combinations of these, are usually described in a semi-formal way, using notions of mathematical informatics (first of all as strings, bags, and trees). Traditionally, such languages are considered as sophisticated subjects. For example, in some countries it is argued that algebra should not be studied in primary school. However, the learning environments discussed here can actually help children to learn formal languages (including programming in icon-based languages) alongside their own written mother language – provided the formal language is used for fulfilling a task that is motivating to the student. There are further interesting environments using other artificial languages such as musical notes and road signs.

Tangible, palpable, movable objects

Students can successfully invent sophisticated information processing procedures dealing (that is, playing) with real objects. For example, operations on real bags of LEGO bricks can be enormously helpful in understanding the operations and algorithms of abstract bags. An emerging dimension here is associated with computerized (including pre-programmed, using feedback) control of different devices acting (moving, imitating industrial processes, or environmental control) in real space. Physical movements and movements of groups of students in real space can be used when mastering certain topics.

Graphical environments on paper or computer screen

It is well known that understanding the operations of structural programming, top-down program design, and other concepts of informatics can be learned effectively with *Robot-in-the-Maze* and other graphical computer environments where a simple *creature* is acting. Basic structures of mathematical informatics have natural graphical presentations as well. A very productive field for learning emerges in combinations of the physical world, its pictorial representation on maps and plans, natural language, and artificial language descriptions.

Real information processes

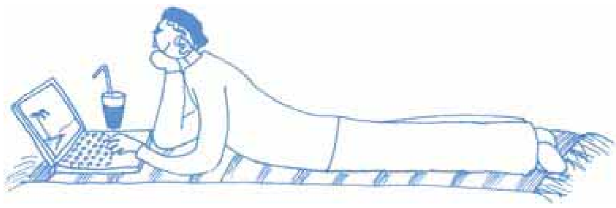
Building up a formal model of a vending machine or a metabolic chain of control in the human body can be an exciting task. Working on such models uses concepts of system, state, interaction, signal, control, and feedback. It is important that these concepts are treated, not in a generalized, abstract, and philosophic way, but as working instruments in real activities of students. The best approach here is thus project-based. The themes and topics of such projects may be as diverse as assembling and operating model cars and toy trains, turning out pop tunes with a synthesizer, drawing animated cartoons, or cracking the codes of mediocre computer games in order to make them more challenging to play.

Human behaviour

Human behaviour can be used for studying formal models for such activities as:

- playing games. Virtually all human games involve mental (information processing) activities. Many games use symbolic environments, formalized rules, random choices and chances, computational and combinatorial reasoning, and strategic planning in an interactive setting;
- planning activities (in projects) and executing plans, acting in groups;
- reasoning and communicating. Of course, these are major human activities. Mathematical informatics studies mathematical models and reflects important aspects of these processes. Among other tools introduced in this context are probabilistic and modal logic;
- learning, including learning mathematical informatics itself: studying, examination and analysis.

Information objects in a computer setting



Text, graphics, hypermedia, and spreadsheets, are all examples of information objects in a computer setting. Consequently, one of the natural ways, but not the only way, to learn mathematics of informatics is to involve practical applications of computers.

Computer programming and its visualization

In a different way from the environment of graphic objects above, we emphasize here the computational aspect with which electronic computers started. There are environments for studying mathematical informatics where effective results can be achieved due to a combination of learning programming with professional programming languages and visualization.

All the learning environments considered in this section can and should be involved in learning mathematical informatics. What is remarkable is that many of these environments were considered for years, and even centuries, to be beyond the frontiers of school mathematics. Problems from these areas were interesting and motivating for students, but considered more as recreational puzzles, not objects of systematic and serious study. Informatics integrates many of these environments and captures their often fundamental importance.

General and specific educational outcomes

The understanding and skills achieved in learning mathematical informatics are helpful in learning other subjects too, as well as being useful in everyday life. One of the important outcomes of studying mathematical informatics is acquiring a natural language with clear and unambiguous semantics. Students try to apply methods of formal reasoning and communication in different areas of life. Sometimes they fail, of course, because of the inadequacy of tools or other factors, but often they succeed.

Other skills that are developed in a framework of mathematical informatics and used in learning different subjects, as well as in a broader context, are classification and sorting, sub-dividing a task into smaller components, planning, and reflection.

7

ICT AND EDUCATIONAL CHANGE

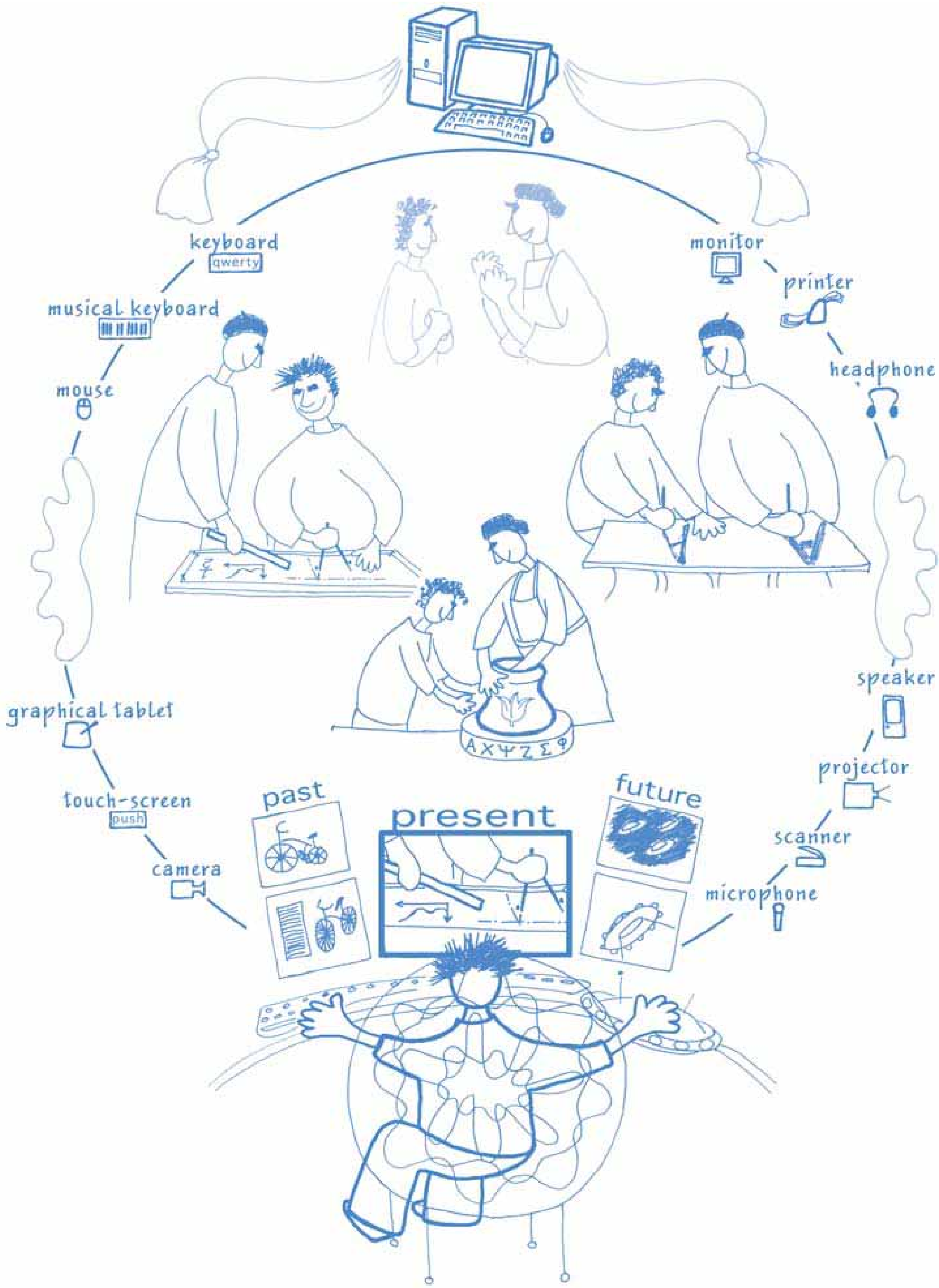
RESTRUCTURING THE FOUNDATION OF SCHOOLS

By permeating contemporary schooling with useful digital technologies, we can make profound changes in the whole existing system of education. However, change is a process, not an event. Just buying and installing hardware and software is not sufficient to make ICT into a genuine educational technology.

This task of implementing ICT in schools demands gigantic efforts, widely time-spread, and covering many diverse but interconnected fields – at the national, regional, and individual school levels. We are talking about restructuring the very foundation of schools, perhaps even greater than the one initiated by the invention of printing press. The utmost precautions must be taken not to destroy, or discard anything of value in current practice. On the other hand, we need to be aware of the really deep changes that have begun in education around the world, and which we must direct and manage with care and courage. This chapter examines strategies of change, stages and indicators of ICT integration, and dimensions of ICT development needed to transform education, and concludes with practical suggestions for planning.

STRATEGIES OF CHANGE

The age-old and seemingly endless debates on education reform, so much fuelled by the new digital epoch, gyrate around two diametrically opposed strategies.


keyboard
qwerty
monitor
printer
musical keyboard
headphone
mouse
speaker
graphical tablet
ΑΧΨΖΣΦ
projector
touch-screen
push
past
present
future
scanner
camera
microphone

The first strategy is directed towards a smooth, gradual improvement of the established system, with major repair where needed, and timely replacement of broken or outmoded components and procedures. This strategy of gradualism stresses the strength of tradition and claims to be a bastion of stability amid a chaotically changing socio-politic and economic environment. In fact, this strategy runs the risk of being an overtly conservative, even reactionary stand that may be vulnerable and shaky in the face of today's challenges and threats.

The second strategy requires a drastic paradigm shift from a classical system of education toward a new one built upon totally different principles. This futuristic strategy sees change as its foremost goal, and as a normal part of the life of a school. In breaking all ties with the past, however, the strategy risks impoverishing itself and its students by neglecting the immense riches of our cultural legacy.

The question is can we find something less risky and more reliable.

Between the two extremes outlined, there is a third strategy that might be called sustainable schooling. By remaining tradition-conscious and wary of orthodox options, the third strategy is nevertheless ready to make yet another explorative move towards the goals of 21st century education. ICT-related reform is essentially a teaching and learning enterprise on a grand scale. We must remember that we have much to learn, both before and during the process of ICT implementation. We are making an adventurous journey through the wilderness where previous travellers may sometimes feel they have gone astray. Thus, what we offer below is not a detailed road map, but rather a list of general travel tips to help us get along the road to our desired destination.

STAGES AND INDICATORS OF ICT INTEGRATION

In many countries and educational communities across the globe, attempts have been made to classify various stages of integration of ICT into general education; and then to determine indicators of ICT integration.

Stages

Several stages of ICT integration in schools have been identified (see, for example, UNESCO 2002b). It is the continuum of stages rather than the actual number of stages that is important:

The earliest stage is the presence of pre-digital (pre-computer) ICT only. We see development of information-communicative competence based on these pre-digital forms (photography, using encyclopedias and library resources) and information processing activities with texts and objects of the material world.

Following on from this stage, awareness of ICT is based on demonstration of ICT with occasional hands-on experience.

A subsequent stage is for some competence in ICT with opportunities to use them for a majority of students and teachers.

Further along the continuum is active and extensive use of ICT in learning and teaching across all subjects in the curriculum.

At the furthest end of the continuum, there is transformation of the school in all areas: curriculum, organizational models of work, and relations with the community.

What is important to note about these stages of ICT integration is that schools do not necessarily progress through them sequentially. It is quite possible for a school having only a few computers and with only a medium level of ICT-competence among teachers to begin a real transformation in one part of the curriculum, say, in History. Indeed, the normal pattern is for transformation to begin in one area and gradually permeate to all areas of a school's activities.

Indicators

The most popular indicator for the success of ICT in education today is the number of students per computer, no doubt because it is easily measured. An alternative indicator would be to consider the results of learning. The problem here is that it is much more difficult to evaluate the effects of a "would be" situation, that is, based on a hypothetical reorganized and correspondingly equipped school. An additional difficulty is that we expect ICT to be effective primarily in those fields and aspects of education that are not central or even non-yet-existing in the traditional school, but vitally important for modern society.

We have therefore a whole spectrum of options for indicators of ICT integration, which include the following, which we list with brief accompanying notes showing what information needs to be gathered for each indicator:

- Money spent

  Budget all monies corresponding to individual ICT programs within schools.

- Technology delivered

  Optimize the types and characteristics of equipment in accordance with school needs and claims.

- Technology installed

  Plan, fix, and check premises, communication (power supplies, grounding), furniture, lighting, theft-protection and insurance.

- Technology available for students and teachers in schools

  Provide personnel to support adequately learning and working activities of students and teachers, and possibly also members of the wider school community; on a 12 hours a day, 7 days a week basis.

- Technology service

  Contract for service, maintenance and upgrade of equipment and software.

- Professional development

  Develop human capacity within schools (in-service training of teachers, librarians and other paraprofessionals).

- Technology planned

  Document ICT implementation plans and exhibit these on school walls or over the Internet.

- Technology being used

  Document time spent, in record-books or on the school server, when teachers and students use computers and the results obtained in class work, homework, and group projects.

- Educational outcomes delivered

  Students are ICT-competent, they learn different subjects more effectively, and achieve higher order goals as independent thinkers, researchers, and creators. Document the results in students' portfolios, and record examination results and independent (including international) evaluation.

A more comprehensive discussion of performance indicators for ICT in education may be found in UNESCO (2003).

DIMENSIONS OF ICT DEVELOPMENT

At all stages of ICT development in schools, across different cultural and economic contexts and across different sized education systems, we can identify certain key dimensions. These include:

- Leadership and vision
- People
- Technology
- Practice

Let us consider these dimensions in more detail.

Leadership and vision

Encouraging citizens to understand and support change is an important component of any educational reform. In the case of ICT, this support and understanding is even more crucial. A positive attitude and active involvement is needed by all the following groups or stakeholders:

- national authorities, officials and legislators – to formulate goals and to allocate resources;
- educational authorities responsible for curriculum matters – to support new systems of educational goals, objectives, and content;
- school principals – to support their teachers and changes in the life of schools;
- teachers – to be brave enough to start;
- parents – to trust teachers; and
- the general public, journalists, NGOs – to understand and interpret what is happening.

All these groups need their leaders to work inside their sphere of influence and to influence and convince other groups and their leaders of actions in ICT-based educational reform. To do this effectively requires vision. In all successful implementations of ICT in schools around the world, a key dimension is always leaders with a strong commitment for ICT and a vision of how ICT can transform teaching and learning within schools.

People

For an ICT-based curriculum to be successfully implemented, another key dimension is people, which means:

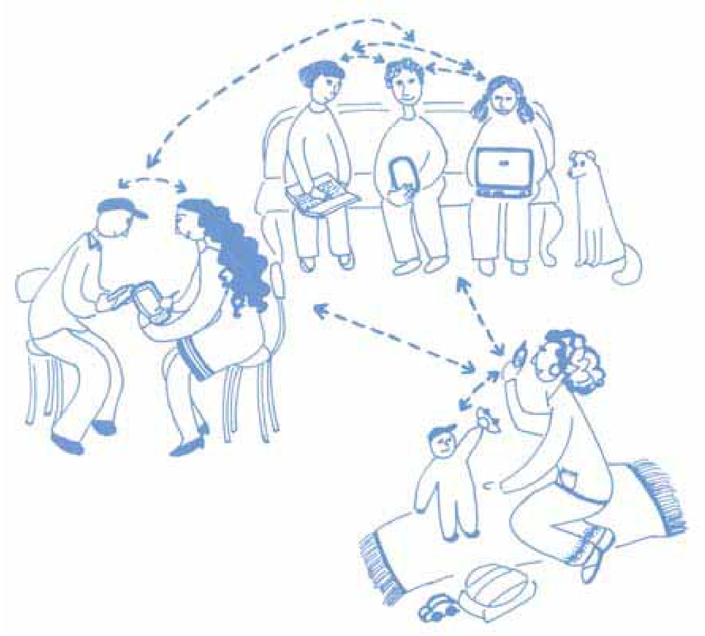
- Supporting teachers who are willing to change their teaching style, to learn new ways of doing things, to reduce the amount of knowledge they assume their students should memorize, and to encourage students to be independent learners within a collaborative environment.
- Incorporating ICT-based learning into teacher preparation and in-service training, relevant for teachers, with components of reflection on their learning and design of their teaching.
- Providing a framework in which ICT usage is accepted as an incentive for promotion.
- Building up a community of educators to share a common vision and experience.
- Supporting and rewarding interaction between teachers of ICT and all the school.
- Introducing a position of ICT-coordinator.
- Using students as appropriate for a technical and intellectual supporting labour force.

Technology

Technology might appear to be an obvious, although expensive, dimension in implementing ICT. Simply, buy computers for schools and sit back and watch for the results. However, as we have tried to show throughout this book, implementing ICT is a complex issue with many different facets.

For a start, equipment is not limited to computers only. We have already listed many types of technological equipment. There is a broad spectrum of pre-computer, or pre-digital technology, worth incorporating within an ICT framework in accordance with our educational goals. Digital devices associated with computers magnify its productivity and effectiveness in school. Too often ICT are thought of as involving computers only.

There is even more misunderstanding about educational software than there is about hardware. The most sophisticated hardware is useless without appropriate software. Investment in technology requires, then, investment in professional or educational versions of software: general applications software, professional applications software, teaching software on CD and DVD, and software systems for the control and management of learning.



The purchase of hardware and software involves also a consideration of:

- Space, together with furniture, power supply, local networking, and installation.
- Maintenance, plus support and upgrade.

Practice

Transforming education means not only changing textbooks and teachers' attitudes, but also altering the prevailing practice in schools, that is, the formal frameworks regulating the educational system. This, then, is another key dimension in implementing ICT in schools. Here are areas of school life that need most to be changed:

- roles of teachers, administrators and other employees, ICT-coordinators, two teachers in the classroom, certification and promotion;
- functions of space for learning activities, architectural and construction requirements;
- access to ICT;
- consumables and supplies; and
- forms of learning activities and evaluation: homework via the Internet; project-based learning; distance education; examinations with full access to information sources.

TRANSFORMATION OF EDUCATION

The four dimensions of ICT implementation in schools discussed above – leadership and vision, people, technology and practice – are essential in the process of transforming education, which is a key theme of this book. At this point, we simply list some of the areas where change is needed:

- goals and objectives;
- content and its sources;
- evaluation and assessment;
- structure of learning activity and interaction between participants;
- job descriptions and working habits; and
- awareness of parents and society.

All of these areas requiring change are discussed in some detail in preceding chapters.

PRACTICAL SUGGESTIONS FOR PLANNING

We conclude this chapter and this book with a few specific suggestions that can be helpful to all those involved in the education process in their planning to use ICT in schools.

- Use all ICT and pre-ICT spatial and visual environments to achieve the new literacy.
- Use technology across the curricula; introduce it with the co-operation of different teachers.
- Use ICT intensively in teacher preparation and in-service training.
- Buy the newest affordable technology, but do not reject donations of reliable equipment provided there are enthusiasts to support it technically.
- Do not lock computers in the computer lab and restrict them to the teaching of computer science and programming to advanced students.
- Create an information environment that incorporates libraries and laboratories and extends beyond their walls.

- Do not provide equipment to the poorest schools or to all schools equally, but to schools that are ready and eager to use them. Use resource centres for other schools to gain experience in and to prepare themselves for ICT implementation.
- Do not forget administrators – their personal use of technology is usually the key to understanding teachers' needs.
- Construct a new education using traditional in combination with modern local and global sources. Build up an informal community of teachers and connect to the international community, the national and international intellectual resources of scientists, industrialists, and officials via networks. Make schools centres of the new information culture.

In conclusion, the best advice we can give to all educational leaders and decision-makers was that given by Lao-Tzu in his immortal book *Tao Te Ching*:

> *The Master doesn't talk, he acts.*
> *When his work is done,*
> *The people say, "Amazing.*
> *We did it, all by ourselves!"*

REFERENCES

Anderson, J. 1993. *The New Literacy and Technology*. Keynote address to the International Reading Association Convention, San Antonio, Texas, April 1993.

Bederson, B., Shneiderman, B. 2003. *The Craft of Information Visualization: Readings and Reflections.* Morgan Kaufmann Publ., San Francisco.

Berdiayev, N. 1915. *Spirit and Machine*. Translated from: Н. Бердяев. Судьба России. М., **1994.**

Berdiayev, N. 1990. *Man and Cosmos. Technics.* Translated from: Н. Бердяев. Судьба России. М., **1994.**

Bibler, V.S. 1996. *Social Theory in the Historical Dimension*. Translated from: В. С. Библер. Мышление как творчество (Введение в логику мысленного диалога) М. **1975.**

Bissett, A. 2002. *Education for Ethics: CP.Snow's 'Two Cultures' Forty Years On*. [Online]. Available: http://www.ccsr.cms.dmu.ac.uk/conferences/ethicomp2002/abstracts/10.html

Bonta, P. 1990. *Building on Intuitions: Music Composition in a Logo Environment.* In Idit Harel (Ed.). 1990. *Constructionist Learning.* MIT Media Laboratory, Cambridge, MA.

Card, S.K., Mackinlay, J.D., and Shneiderman, B. (Eds). 1999. *Readings in Information Visualization: Using Vision to Think*. Morgan Kaufmann.

Eckert, P. 1989. *Jocks and burnouts*: *Social categories and identity in the high school.* Teachers College Press, New York.

Farnham-Diggory, S. 1990. *Schooling*. Harvard University Press, Cambridge, MA.

Friedhoff, R. and Benzon, W. 1989. *Visualization: The Second Computer Revolution*. Harry N. Abrams, New York.

Gardner, H. 1983. *Frames of Mind: The Theory of Multiple Intelligences*. Basic Books, New York.

Gardner, H. 1991. *The Unschooled Mind*: *How children think and how schools should teach*. Basic Books, New York.

Gardner, H. 1993. *Multiple Intelligences: The Theory in Practice*. Basic Books, New York.

Gargarian, G. 1990. *Music composing as problem solving*. In Idit Harel (Ed.). 1990. *Constructionist Learning*. MIT Media Laboratory, Cambridge, MA.

Gibson, W. 1984 (Reissue edition 2003). *Neuromancer*. Ace Books, New York.

Heineke, W.F. and Blasi, L. (Eds). 2001. *Methods of Evaluating Educational Technology*. Information Age Publishing, Greenwich, Connecticut.

Kosko, B. 1993. *Fuzzy Thinking: The New Science of Fuzzy Logic*. Hyperion, New York.

Moore, G.E. 1997. *An Update on Moore's Law*. Intel Developer Forum Keynote Speech (30 September). [Online]. Available: http://developer.intel.com/pressroom/archive/speeches/geni.93097.htm

Mumford, L. 1967. *The Myth of The Machine: Technics and Human Development*. Harcourt, Brace and World, New York.

Murphy, D. 1995. *Comenius: A Critical Reassessment of His Life and Work*. Irish Academic Press, Dublin.

Negroponte, N. 1995. *Being Digital*. Alfred A. Knopf, New York.

OpenOffice.org. 2004. [Home page of OpenOffice.org]. [Online]. Available: http://www.openoffice.org

Papert, S. 1981. *Mindstorms: Children, Computers, and Powerful Idea*s. Basic Books, New York.

Papert, S. 1993. *The Children's Machine: Rethinking School in the Age of the Computer*. Basic Books, New York.

Perelman, L. J. 1992. *School's Out: Hyperlearning, The New Technology, and the End of Education*. William Morrow and Company, New York.

Pick, K. *John Amos Comenius – Father of Modern Education*. [Online]. Available: http://www.waldorfhomeschoolers.com/comenius.htm

Resnick, M. 1997. *Turtles, Termites and Traffic Jams: Explorations in Massively Parallel Microworlds*. MIT Press. See also: http://web.media.mit.edu/~mres/

Rhodes, J. 1991. *Conceptual Toolmaking: Expert Systems of the Mind*. Basil Blackwell, Oxford.

Rieber, L. P. 1995. A historical review of visualization in human cognition. *Educational Technology Research and Development*. 43 (1), 45-56.

Scheler, M. 1958. *Philosophical Perspectives* (Translated by O. Haac). Beacon Press, Boston.Sternberg, R.J. 1984. *Beyond IQ: A Triarchic Theory of Human Intelligence*. Cambridge University Press, New York.

Stange, K. *Intertwining the two cultures in the year two thousand*. [Online] Available: *http://twstange.com/publications/intertwining2cults.html*

Sternberg, R.J. 1985. *Beyond IQ: A Triarchic Theory of Human Intelligence*. Cambridge University Press, New York.

Sternberg, R. J. 1986. *Intelligence Applied: Understanding and Increasing Your Intellectual Skills*. Harcourt, New York.

Sternberg, R.J. 1988. *The Triarchic Mind: A New Theory of Intelligence*. Viking Press, New York.

TCO. 2004. [Home page (English version) of TCO]. [Online]. Available: http://www.tco.se/TCO_english-index.asp

Toffler, A. 1970. *Future Shock*. Random House. New York. p. 6.

UNESCO. 2002a. *Information and Communication Technologies in Teacher Education: A Planning Guide* (Ed. P. Resta). UNESCO, Paris. [Online]. Available: http://unesdoc.unesco.org/images/0012/001295/129533e.pdf

UNESCO. 2002b. *Information and Communication Technology in Education: A Curriculum for Schools and Programme of Teacher Development* (Eds J. Anderson and T. van Weert). UNESCO,Paris.[Online].Available: http://unesdoc.unesco.org/images/0012/001295/129538e.pdf

UNESCO. 2003. *Performance Indicators for ICT Use in Education*. UNESCO, Bangkok. [Online]. Available: http://www.unescobkk.org/ips/ebooks/documents/ICTindicators/ICTindicators.pdf [Accessed 15 March 2004].

UNESCO-IBE. 1995. *Teacher Training and Multiculturalism: National Studies*. IBE, Geneva.

Vygotsky, L.S. 1978. *Mind in Society*: *The development of higher psychological processes*. Harvard University Press, Cambridge, MA.

Vygotsky, L.S. 1986. *Thought and Language.* MIT Press, Cambridge, MA.

W3C World Wide Web Consortium. 2004. [Home page of W3C]. [Online]. Available: http://www.w3.org

Whitehead, A.N. 1963. *The Aims of Education and Other Essays*. Mentor Books, New York.

GLOSSARY

Basic – a high-level procedure language, elaborated in 1964 by John Kemeny and Thomas Kurtz from Dartmouth College, USA. Initially the language was realized as an interpreter, which facilitated essentially computing and particularly program adjustment. Now there are also compilers of Basic. Basic suited the first microcomputers well since it occupied as little as 4-8 kilobytes of Operating Storage Device. The title dates back to Beginner's All-purpose Symbolic Instruction Code. There are many dialects: Basica (IBM), GW-Basic, MSX-Basic, Turbo-Basic (Borland), Quick-Basic (Microsoft), XYBasic, QBasic, CBasic, Basic-80, 86 and 87Basic, 387Basic (MicroWay).

Bit – a minimal unit of information that enables us to discern and choose between two opposite alternatives, such as 1 or 0, yes or no, light or dark, that is the presence or absence of something.

Browser– Tool used to access and manipulate information on the Web (e.g.- Netscape Navigator, Internet Explorer).

Byte – a unit of information that is equal to 8 bits.

CAD – Computer Aided Design – a system of automated projecting.

CAM –

1. Communication Access Module – a module of the access to connection channel.

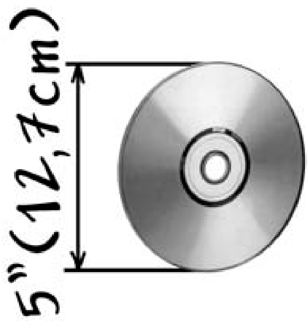
2. Computer Aided Manufacturing – an automated system of production and technological processes management.

3. Common Access Method – a standard access method for SCSI (Small Computer Systems Interface).

4. Content-addressable memory – associative memory. Synonyms – data-addressed memory.

CAI – Computer Aided [Assisted] Instruction – a package for learning in a subject or topic (e.g. mathematics or handling a spreadsheet). Modern CAI makes extensive use of multimedia tools.

CD-ROM – Compact Disc-Read Only Memory – a silver-coated optical disc that stores up to a gigabyte of information as an optical trace. A CD (Compact Disc) is widely used for storing music or text, whereas a CD-ROM commonly stores a range of multimedia. Previously, CDs were readable only but now also come in rewritable form. CD burners are becoming common peripherals.



Chat – exchanging information (a text dialogue) in real time; a conversation (on the Internet).

Chip – (from *microchip*) – a micro-scheme, crystal; general name of an integral scheme.

Computer Games – a category of software, computer games are sub-divided into several classes: arcade games, adventure games, and logical games.

Constructivism – A theory and teaching strategy holding that learners actively acquire or "construct" new knowledge by relating new information to prior experience. It contrasts with strategies that rely primarily on passive reception of teacher-presented information.

CPU – Central Processing Unit – a part of a computer directly accomplishing the machine's commands, a program. Comprises a register file.

CRT – Cathode Ray Tube – previously, a widespread display name.

Cursor – generally of two kinds: a text cursor and a mouse cursor. A text cursor is a twinkling symbol on the screen (usually a vertical line) showing a place to enter the next symbol. A mouse cursor is a graphical sign (usually an arrow) reflecting the mouse movements on the screen and the operations made with its help.

Cyberspace – **1.** virtual space created by a computer system. It can be shaped from a simple global network from electronic mail to the breaking worlds of virtual reality.

2. A term invented in 1984 by the writer William Gibson in his novel *Neuromancer*. Now, the word is used to denote a whole range of information resources accessible through a computer network.

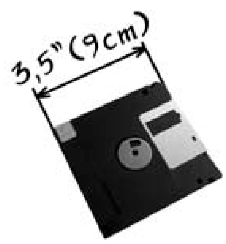
Digital Camera – a camera using a ROM matrix from which images are recorded to a non-energy dependent flash memory in digital form. Pictures already taken may be downloaded to a computer to be edited or printed through a standard port.

DVD – *see* Digital Versatile Disc.

Digital Versatile Disc – like CD is an optical disc but with the capacity to store 10GB or more information, more than sufficient to hold a full-length movie.

DVI – Digital Video-Interactive – the Intel Corporation standard. Provides a high machine level of pressure of whole-screen videos being recorded to optical disk (licensed by IBM).

Floppy disk – a removable magnetic disc, usually called diskette, for storing relatively small amount of computer-processed data and information outside a computer's body, and/or moving that amount from one computer to another.



GIS – Geographic Information System – a class of program systems connected with input, processing, storing, and displaying space data, such as locality plans and schemes.

GUI – Graphical User Interface

1. A machine creating a graphical user interface for the OS.

2. A program allowing execution of data visualization.

Hard Copy – a file copy or content of the screen on paper, film or other non-electronic carrier.

Hard Disks – a computer device directly accessible for storing and retrieving large volumes of programs and data.

HDTV – High Definition Television – a technology and standard of transmitting and receiving television signals with the capacity of 1125 lines, doubling the capacity provided by current technology.

Hyperlinks – active text image or button marked in colour on a web page, a click on which (a hyperlink activization) takes the user to another page or another part of the current page.

Hypermedia – an extension of *hypertext* to include other media such as sound, graphics, and video.

Hypertext – a term coined by Ted Nelson in 1965 before the Internet and the World Wide Web made it useful to refer to non-linear text containing *hyperlinks* that with the aid of a browser enable a reader to branch to other documents or other parts of the current page.

IC – Integrated Circuit – semi-conducting device comprising several electronic elements.

Interface – a system of hardware and software components responsible for transforming and converting electronic signals that carry relevant information into visual, aural and tactile patterns perceptible by human senses.

Joystick – a device held in the hand similar to a gearshift to control the cursor on screen, and used extensively in arcade computer games.

Keyboard – an indispensable part of computer which looks like typewriter's keyboard and serves mostly for alphanumerical text input.

LCD – Liquid Crystal Display – a type of display used in watches, calculators, flat screens, portable PC screens, and other devices. Liquid crystals can change their molecular structure, which allows the management of light flow to pass through them.

LED – Light Emitting Diode – a low consuming electronic device giving light when undergoing penetration of the electric light.

Linux – a freely distributed (non-commercial) dissemination of the UNIX OS on PC and other platforms.

Macintosh – **1.** A generic name for computers produced by Apple Computer Company, and commonly referred to as *Macs*.
2. A prefix in the names of software products denoting that the product is meant for the Macintosh PC.

Magnetic Tapes – Tapes with surfaces covered with magnetic material.

Microchip – generic name of an integrated circuit.

Microsoft – The biggest software developer in the world, founded in September 1975 by Bill Gates and Paul Alan.

MIDI – Musical Instrument Digital Interface – a standard protocol for coupling electronic musical instruments with a computer and software, developed in 1983.

Monitor – (display) an indispensable part of a computer, which serves to display visually the processed alphanumeric and graphical information on a screen, as well as to receive the user's working commands, given through the mouse or equivalent control device.

Mouse – a handheld control tool with one, two or three buttons to operate a computer by moving the mouse plastic body across the flat surface (usually table-top covered with a small mat called a mousepad), while watching the corresponding cursor movements and selecting appropriate controllable objects on the monitor screen.

Notebook – a class of portable computers of notebook size weighing less than 4 kg.

OCR – **1.** Optical Character Recognition – automated recognition (with the aid of special programs) of graphical images, symbols, printed texts (e.g. entered into a computer by a scanner), and their transformation into a format suitable for processing by text processors and text editors.
2. Optical Character Reader – a device to optically recognize symbols or automated text reading.

Optical Disks – see *CD-ROM* and *DVD*.

OS – Operating System – electronic instructions providing an environment for executing applications and providing access to computer devices.

Output – 1. Data of any kind sent from a computer system. A polysemantic word used as a noun, a verb, or adjective.
2. General name for data shown on a display device; also for data sent to another program or over a network.

Palm, or
palm-top – a tiny, thin handheld pocket computer.

Pattern – a distribution of events in a time and/or space continuum, which we can recognize and nominate, then compare to some other pattern and, finally, discern the former from, or identify with, the latter.

PC – Personal Computer – though the term *PC* is sometimes used to denote any personal computer, it often denotes a PC that uses the Intel processors. The term originates from IBM PC, produced in 1981 by the IBM Corporation as a computer to be operated by an individual, in contrast to mainframe computers.

Personal Digital Assistant (PDA) – A handheld computer that often includes pen-based entry and wireless transmission to a cellular service or desktop system.

Performance indicators – Descriptions of behaviors that demonstrate acquisition of desired knowledge, attitudes, or skills.

Pixel – a minimal addressable element of a double-raster image whose colour and brightness can be set independently from other points; refers to the capacity of the graphical adaptor and is usually given in pixels, for example, for VGA it is 640 x 480 in a 16-colour palette.

Portal – a website designed to provide integrated information in a particular field or fields. Usually contains references to other sites whose content meets requirements of the portal's visitors. Portals may be specialized focusing, for instance, on maritime archaeology, or general like certain search engines that offer a range of information services (weather, news, currency rates, and information directory).

Printer – a device that transforms the computer screen texts and images into matters printed out on paper or film (so called hard copies).

Productivity tools – Productivity tools refer to any type of software associated with computers and related technologies that can be used as tools for personal, professional, or classroom productivity (e.g. Microsoft Office, Apple Works).

Projector – an electronic-optical device, emitting a strong beam of light to cast the computer monitor images onto a large screen

RSI – Repetitive Strain Injury – a type of professional disease associated with working on a keyboard caused by overuse or misuse.

Scanner – an optical device for entering data of digital text or graphical information from a physical source (e.g. from a photo) into a computer. Scanners are characterized by the colour depth and dynamic range of colours recognized.

Search engines – Software that allows retrieval of information from electronic databases (library catalogs, CD-ROMs, the Web) by locating user-defined characteristics of data such as word patterns, dates, or file formats.

Sensor – a device producing an electric reaction signal to a range of phenomena: temperature, movement, tension, vibration, colour, magnetic field, concentration of certain chemical substances.

Server – a computer providing services, resources, or data to a user's computer.

Simulation program – A computer program that simulates an authentic system (city, pond, company, organism) and responds to choices made by program users.

SVGA – Super Video Graphics Array – a standard for graphics display and a video adaptor to realize it. Provides a greater capacity than the VGA standard.

TCO – Total Cost of Ownership – the term was first used in autumn 1995 in a report of the Gartner Group. TCO'92 – the first norms worked out by the Swedish conference of professional employees appeared in 1992 to regulate the parameters of display from the point of view of electronic security, electricity consumption, and electric magnetic fields influence.

Touch screen – an input device allowing a user to interact with a computer by touching pictograms or graphic buttons on a display with one's finger. Finding the coordinates of a surface touched is pinpointed by the conjunction of infrared rays net by a finger situated on the display surface.

UNIX – an open multi-user operating system developed in 1969 by Ken Thompson and Dennis Ritchie at AT&T Bell Labs, now realized on many computer platforms.

UPS – Uninterruptible Power Supply – a device comprising accumulators providing the power supply and security for a computer and peripherals in case of a decrease or change in power of the basic power supply source; also a means to save data reliably and automatically when switching off.

UXGA – Ultra Extended Graphics Array – a video graphic standard for the display extension 1600 x 1200 pixels.

VR – Virtual Reality – a complex modeling system of a pseudo-physical reality shaping three-dimensional visual worlds accessible to a user with the help of a powerful computer and such accessories as stereoscopic glasses, gloves, and helmet. Information about the activity of the user comes to the computer from devices registering a user's posture and movements.

VRML – Virtual Reality Modeling Language – a language allowing description of three-dimensional scenes that use animation and travel along the Web for different projects on the Internet. Initially it was elaborated by the Silicon Graphics Company and was called Virtual Reality Mark-up Language.

XGA – Extended Graphics Array – an IBM standard of 1991 on video graphics in the family of PC/2 machines; an adaptor and a microscheme realizing this standard. Supports a higher capacity (1024 x 768, 256 colours) as compared to VGA (considered as part of the SVGA family).

World Wide Web (WWW) – 1. The worldwide array of hypertext transfer protocol (http) servers allowing access to text, graphics, sound files, and more to be mixed together and accessed through the Internet.

2. Used loosely to refer to the whole universe of resources available using Gopher, FTP, http, Telnet, USENET, WAIS, and some other tools.

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Education for All (EFA) is the foremost priority of UNESCO – because it is a fundamental human right and a key to sustainable development and peace within and among countries. Achieving the goals set in Dakar and at the Millennium Development Summit entails a commitment to a triad embracing *access, equity* and *quality* in primary and secondary education. This Handbook is designed for teachers and all educators who are currently working with, or who would like to know more about, information and communication technologies in schools. The technologies involve much more than computers, and so the abbreviation we use for information and communication technologies – ICT – is a plural term to denote the whole range of technologies associated with processing information on the one hand and, on the other, with sending and receiving messages.

A major theme of this Handbook is how ICT can *create new, open learning environments*. More than any other previous technology, ICT are providing learners access to vast stores of knowledge beyond the school, as well as with multimedia tools to add to this store of knowledge. ICT are largely instrumental, too, in shifting the emphasis in learning environments from teacher-centred to learner-centred; where teachers move from being the key source of information and transmitter of knowledge to becoming guides for student learning; and where the role of students changes from one of passively receiving information to being actively involved in their own learning.