United Nations
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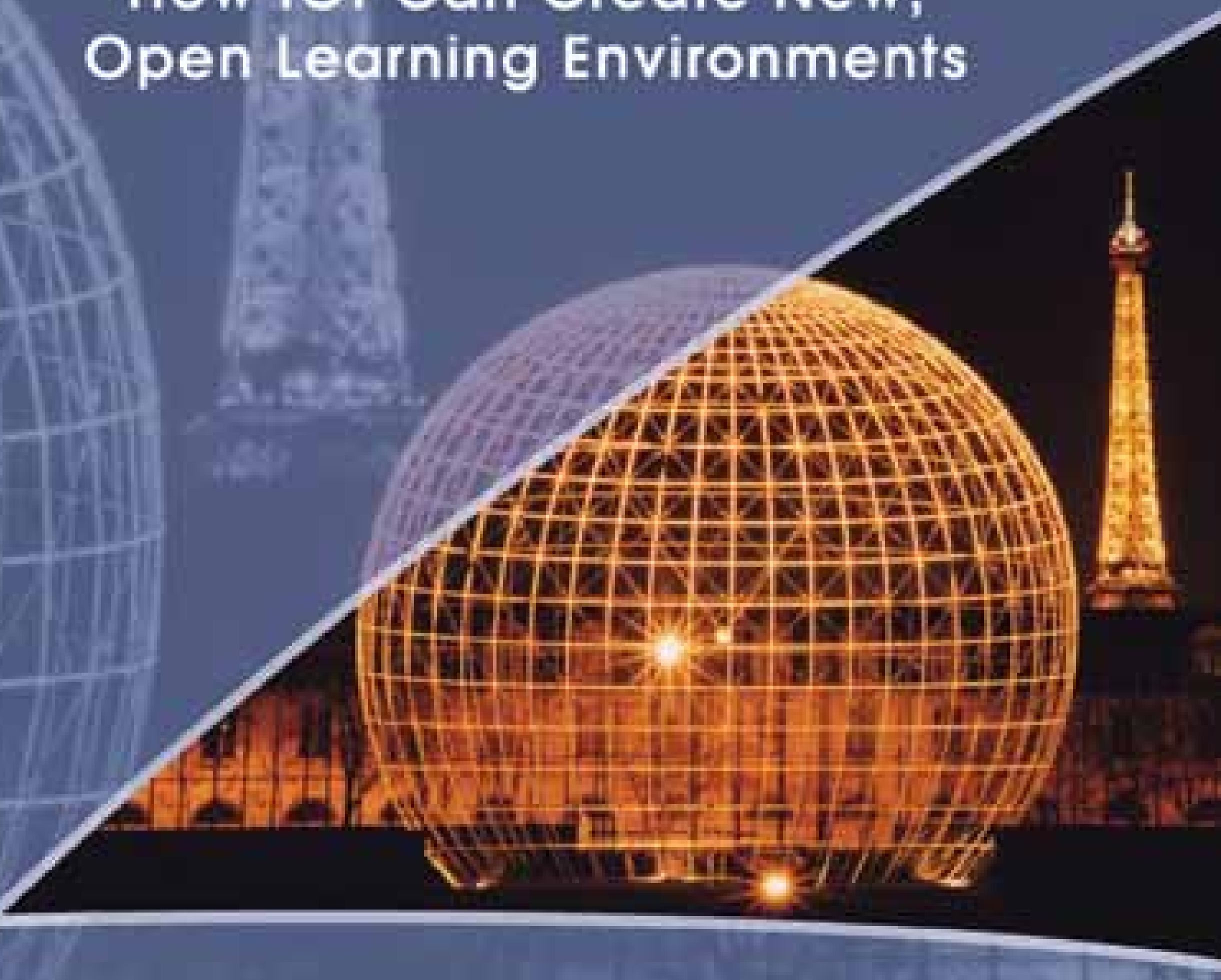
INFORMATION AND COMMUNICATION TECHNOLOGIES IN SCHOOLS

A HANDBOOK FOR TEACHERS

or

How ICT Can Create New, Open Learning Environments



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How ICT Can Create New, Open Learning Environments

UNESCO, 2005

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FOREWORD

All governments present at the World Education Forum in Dakar, Senegal, April 2000, pledged to achieve a number of essential goals aimed at ensuring Education for All (EFA). I will mention only two of them that are particularly relevant for, and lie at the basis of, the development of this new publication - *ensuring that the learning needs of all young people and adults are met through equitable access to appropriate learning and life-skills programmes* (Goal 3) and *improving all aspects of the quality of education […] so that recognized and measurable learning outcomes are achieved by all* (Goal 6).

This new publication, initiated by the Division of Higher Education, entitled "*ICT in Schools: A Handbook for Teachers or How ICT Can Create New, Open Learning Environments*", should be seen as complementary to the ones already published by the Division in the 2002-2003 biennium devoted to the use of information and communication technologies (ICT) in teacher education. The present handbook is principally designed for teachers and teacher educators who are currently working with, or would like to know more about, ICT in schools.

A major theme in the book concerns how ICT can create new, open learning environments and their instrumental role in shifting the emphasis from a teacher-centred to a learner-centred environment; where teachers move from being the key source of information and transmitter of knowledge to becoming a collaborator and co-learner; and where the role of students changes from one of passively receiving information to being actively involved in their own learning.

Evidence over the past years has clearly indicated that efforts to ensure equal access to educational opportunities and quality education for all must be accompanied by wide-ranging education reforms. Such reforms are not likely to succeed without addressing the new roles played by teachers in preparing students for an emerging knowledge-based and technology-driven society. Teachers must have access to adequate training and ongoing professional development and support and be motivated to use new teaching and learning methods and techniques.

Information and communication technologies must be harnessed to support EFA goals at an affordable cost. They have great potential for knowledge dissemination, effective learning and the development of more efficient education services. This potential will not be realized unless these technologies serve rather than drive the implementation of education strategies. To be effective, especially in developing countries, ICT should be combined with more traditional technologies such as books and radios and be more extensively applied to the training of teachers.

Education must reflect the diversity of needs, expectations, interests and cultural contexts. This poses particular challenges under conditions of globalization given its strong tendency towards uniformity. The challenge is to define the best use of ICT for improving the quality of teaching and learning, sharing knowledge and information, introducing a higher degree of flexibility in response to societal needs, lowering the cost of education and improving internal and external efficiencies of the education system.

I sincerely hope that this new publication will be both informative and useful for a wide range of users who all believe in, and pursue, a common goal - *Quality Education for All*.

John Daniel
Assistant Director-General for Education

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PREFACE

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.

However, this handbook is not primarily about hardware (the term applied to computers and all the connecting devices like scanners, modems, telephones, and satellites that are tools for information processing and communicating across the globe): it is about *teaching*, and, more particularly, *learning*, and the way that all these technologies that we group under the acronym ICT can transform schools as we currently know them.

ICT have already impacted on the economies of all nations and on the fabric of society at every level within which teachers and students live and interact. In so far as ICT have the potential to impact similarly on every aspect of the life of a school, the coverage of this handbook is very broad and includes - to mention just one topic from each chapter - educational technology of the mind, multimedia presentations, multiple intelligences, wearable computers, goals of education, and information objects.

Although the handbook coverage is necessarily broad, much of the content is quite specific and directed to teaching and learning activities with ICT in the classroom. Thus there are sections on modelling forms and meanings of reading, writing, and oral communication, or the *new literacy*, as we prefer to call them. Other sections embrace science experiments, foreign language learning, research in social sciences and humanities, and the mathematics of informatics.

The handbook, then, is for teachers at all levels, from kindergarten through elementary, middle, and high school. Further readers who should find this handbook useful are those in pre-service teacher education courses at colleges and universities who are preparing to become teachers. Classrooms that they will enter promise to be very different environments from those when they themselves went to school, thanks largely to developments in ICT.

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.

Two other recent UNESCO publications complement this handbook nicely. These are *Information and Communication Technologies in Teacher Education: A Planning Guide* (UNESCO 2002a); and *Information and Communication Technology in Education: A Curriculum for Schools and Programme of Teacher Development* (UNESCO 2002b). Both publications are available online (see References for full details).

This handbook consists of seven chapters that together provide a comprehensive treatment of ICT in schools within the context of broader movements in society and the world at large.

The first chapter, *Society, Learning Imperatives, and ICT* is intended to provide basic perspectives of:

- society, peoples, individuals, and their needs;
- educational systems to serve society and individuals; and
- ICT as a powerful and versatile means to support socio-cultural development, especially in the field of education.

The second chapter, ICT: *New Tools for Education*, is devoted to technical matters. ICT are described here on the basis of little prior knowledge. However, this chapter should be useful for ICT-using educators as well.

The third chapter, *Schools in Transition*, contains a systematic overview of the traditional or *classical* school with its strong and weak points, its problems, prospects and possible solutions for further development. Some of the solutions we suggest can be implemented with the help of ICT; other solutions should be taken into consideration while introducing ICT into schools.

The fourth chapter, *ICT in Learning and Teaching*, investigates the elements, or atoms of teaching and learning activities in view of different kinds of support, improvement, and extension made possible by ICT. From *atoms*, the chapter moves to more complex teaching and learning activities or *molecules*.

The fifth chapter on *Structuring the School Continuum* covers the problems of practical use of ICT in schools and offers possible solutions.

The sixth chapter on *Mathematical Fundamentals of Information Science* focuses on the fundamentals of computer science and technology (or educational informatics). These fundamentals are relevant for different ICT applications and belong to what we call the *new literacy*.

The final chapter on *ICT and Educational Change* brings together the several key themes that underlie this book: the need to restructure schools, strategies of change, and dimensions of ICT development. A final section puts forward practical suggestions for planning.

References to all works cited, a *glossary* of key terms, and an *index* for ready reference complete this handbook.

1

SOCIETY, LEARNING IMPERATIVES, AND ICT

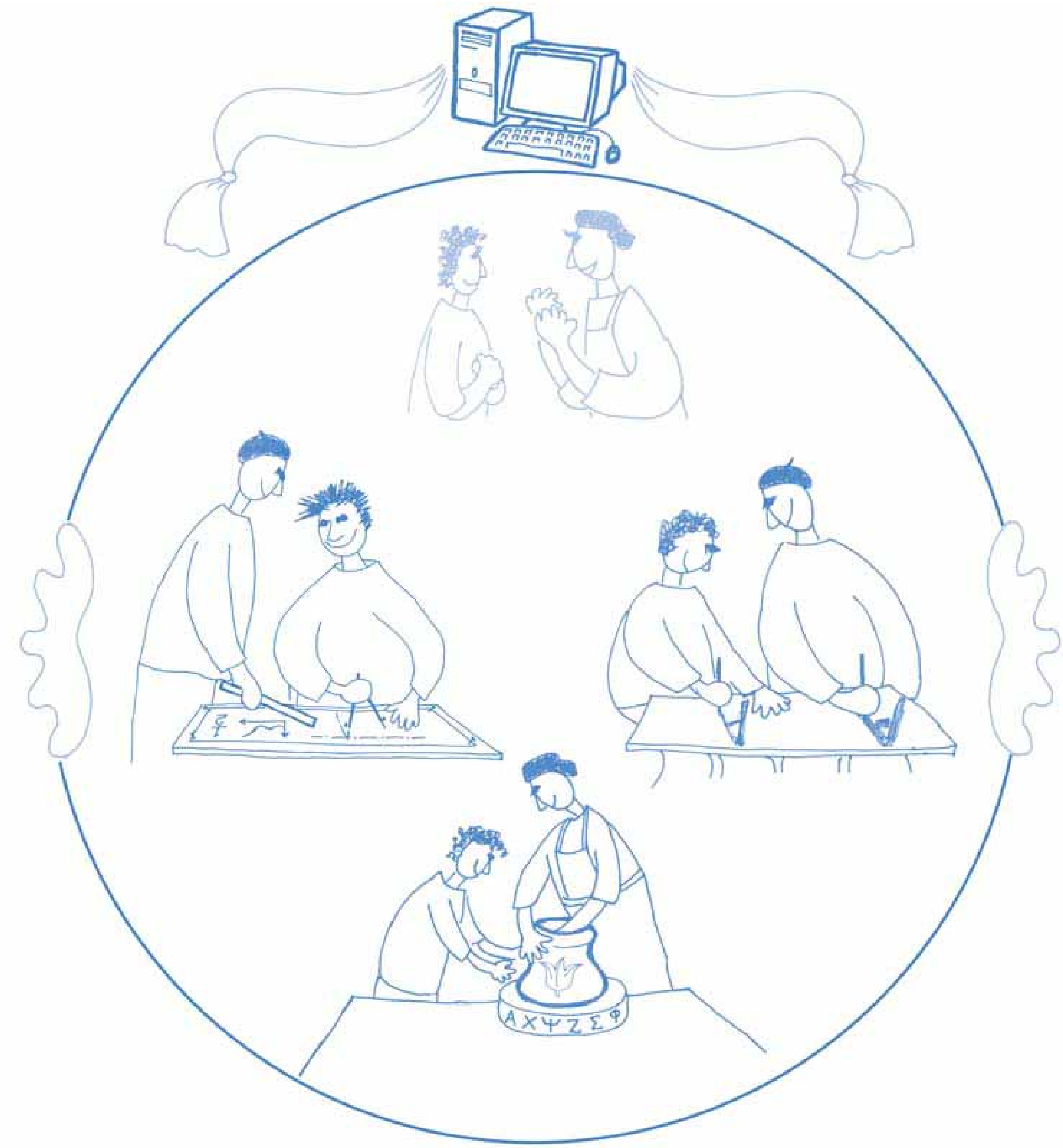
SOCIETAL PERSPECTIVES

The shock of the future

Modern civilization is characterized by the growing pace of change. The economy now undergoes a radical transformation (including the structure of the labour market and requirements for job qualifications) within a single generation. Because of the enormous difficulty in understanding, appreciating and even surviving change, we talk about the impact of these changes as future shock. On the other hand, these fundamental shifts do not appear suddenly, as bolts from the blue: they are always a part of a longer historical evolution, in which technological development plays a part.

It is not out of place to cite Alvin Toffler who coined the term *future shock* about forty years ago:

> In dealing with the future, at least for the purpose at hand, it is more important to be imaginative and insightful than to be one hundred percent "right". Theories do not have to be "right" to be enormously useful. Even error has its uses. The maps of the world drawn by medieval cartographers were so hopelessly inaccurate, so filled with factual error, that they elicit condescending smile today…Yet the great explorers could never have discovered the New World without them. (Toffler 1970)



We believe that ICT will be a key factor in future positive change – provided they are in the possession of people who use them creatively and for the common good.

Mindcraft economy

The economy has classically been divided into agricultural, manufacturing and service sectors. Today, these sectors have been joined by a fourth category: the booming *knowledge sector* consisting of *knowledge workers*. In an increasingly 'smart' automated environment, mental work is moving from crunching and tossing data to creating information and knowledge, and then communicating, exchanging and sharing it with fellow-workers. In short, as it was already noted more than decade ago, *mindcraft* is replacing *handicraft* (Perelman 1992). The ubiquitous computer and its related ICT devices have become critical tools for much of the world economy.

At the same time, *knowledge work* has become, not just another sector but a cross-sectional drive, a main carrier, and a cutting edge for contemporary economic activities. Observers talk about the emerging *mindcraft economy* of the 21st century, an economy that presupposes continuous learning within elaborate systems that combine human agents and intelligent ICT-based machines.

Globalization and ICT

One of the major trends in the global economy is the movement of material industries from developed to developing countries. This process involves information industries as well. While this change is positive in many ways, the distribution of wealth is unequal and much of the world continues to suffer from severe problems of poverty, hunger and illiteracy. At the same time, more countries have a chance to take leading roles in the new information or knowledge society, which generally assumes a multi-centrist and multi-cultural worldview. ICT can help educators achieve this kind of society by creating opportunities for:

- greater individual success, without widening the gap between the poorest and the richest;
- supporting models of sustainable development; and
- more countries to build and use information space, rather than having a few countries and mass media monopolies dominate dissemination of information and culture.

The world's most serious problems – the growing demand for food, shelter, health, employment, and quality of life – cannot be solved without highly efficient new technologies. With the advantages of being nature-protecting, non-polluting, less energy consuming, and more human-friendly, ICT applications are becoming indispensable parts of contemporary culture, spreading across the globe through general and vocational education.

Technology – a double-edged sword

ICT already influence the social and political life of all nations. However, their influence is not always for the better. The use of message-forming and transmitting technologies in some cases impedes justice and concentrates power by reducing reciprocity in communication. Emergence of huge media conglomerates is vivid evidence of this.

Even more impressive lessons, both warning and encouraging, can be drawn from the recent history of the fall of great totalitarian states. One might suggest that the fall of the Soviet communist empire had already begun when Joseph Stalin died in 1953. Not coincidentally, the change to a more liberal regime coincided with the proliferation of TV broadcasting and the introduction of home tape-recorders in the USSR. The impact of those types of ICT was equally significant but different in its directions and consequences. Television, owned by the state, became, and for the next forty odd years remained, another tool for *vertical* brainwashing and manipulation of public consciousness, exercised by the totalitarian regime.

The same historical period was marked by a rising tide of underground dissemination of the written word (and, if caught, severely punished). Forbidden manuscripts of prose, poetry, political philosophy, social critique, and reports on violations of human rights were duplicated on mechanical typewriters that produced four carbon copies at a time. Photostat copying was too complicated and demanded special skills to be used widely. In the early 1970s, the old fashioned photostat copier was supplanted by the electrochemical xerox copier, which was extremely fast and easy to operate, but kept under strict police surveillance in governmental offices and inaccessible to private persons. Fax machines followed a decade later, giving additional impetus to the already visible process of decay and disintegration of the totalitarian stronghold. Toward the end of the 1980s, communication barriers (censorship, radio jamming, and all that) went tumbling down along with the Berlin Wall.

Future generations of historians may be tempted to interpret ICT as the main leverage for all these cataclysms. Needless to say, it would be an obvious exaggeration. History paves its way through time by much more complicated trajectories. In fact, Mikhail Gorbachev ascended to power and launched his famous *Perestroika* (re-building) before such novelties as the Internet, and even phone-fax, had become common commodities in the USSR.

Nonetheless, it would not be too strong an exaggeration to say that the personal computer (with printer and modem to connect the Internet), neglected by short-sighted Soviet authorities, hammered the last nail into the coffin of communist ideological and political rule in Russia and Eastern Europe.

Similarly, we believe that the worldwide proliferation of ICT will help offset cultural imperialism, ideological totalitarianism, and information monopoly. The Internet and desktop publishing will play a crucial role in democratizing the dissemination and use of information. In addition, ICT create new options for the preservation and revival of indigenous cultural traditions and spiritual values. Even a teacher with a class of students, can design a set of fonts for their native language, make a multilingual dictionary, record folk songs and dances, make pictures of handicrafts, and put everything together as an Internet page. We hope that linguistic barriers such as the historically and politically imposed dominance of a few languages may be weakened by the worldwide availability of ICT and its thoughtful application for educational purposes.

Finally, ICT also change age and gender distribution and opportunities in the work place. Women and young people can learn to use ICT and work in ICT environments as well as men.

Individual needs and expectations of society

Life in the new knowledge society demands more independent and responsible behaviour and much less routine execution of orders. To prosper, and sometimes even to survive, people now need to be able to make responsible decisions in new and unexpected situations. Most of all, they need to continue to learn throughout life. Individuals seek to use ICT for personal growth, creativity and joy, consumption and wealth. They also need to be able to analyze mass media information critically and to use it productively.

These individual needs require knowledge and skills to search for information, to analyze, synthesize, evaluate, channel, and present it to others, and to exercise judgment in order to predict, plan, and control fast changing events. The skills noted above are indispensable to ICT-supported and non-ICT learning environments. However, more and more industrial, professional, and business occupations call for knowledge-based and skilful intellectual work. A worker's ability to use ICT fluently is necessary in more and more occupations. Former skills have become obsolete. The abilities to make pen-and-paper arithmetic calculations, for example, or to write in calligraphy, are now viewed as specialized abilities (though both are still useful in the education of students).

At the same time, it is now vital for every child, adolescent, and adult to have at least a general notion of their technological surroundings at home and at school, on the street, in the office and work place. To be sure, any new technology brings dangers and temptations. A recent example of such risks is encouraging a *grasshopper mentality*, as seen in much of the Internet surfing across content, and the pollution of the Internet environment.

Now, what can we as educators do in carrying out our mission, and how can ICT be used to enrich learning opportunities in our schools?

It is essential to develop a vision of the future. This is true, not only because the world is becoming a knowledge society, relying heavily on new knowledge, skills and experiences, but also because we live in a technologically dominated socio-economic milieu that is based on short-term consumer-driven goals of production, and only secondarily on holistic, long-term concern for sustainable development. With our minds fixed narrowly on the technology that supports a comfortable life – even school life! – we may forget, or even act in conflict with, humane and democratic values.

Radical changes needed in school

In the 21st century, the ever-increasing needs of individuals and society are placing a heavy burden on established educational institutions. At the same time, traditional structures and modes of teaching appear less and less responsive to the challenges of our turbulent times. There is a clarion call for innovation and transformation among educators everywhere, especially in the elementary school, the most crucial stage in the development of a human being. Furthermore, the internal problems of schooling are inseparable from external changes on a global scale, and must be seen in the context of contemporary world problems. These, in turn, will not be solved unless approached and treated educationally, as well as economically, politically, and socio-culturally.

Students who enter school are communicative, curious, creative, and capable of learning many things. They have proved this already by mastering a mother tongue, physical motion, complicated games, and many other life skills. However, we believe that the traditional school of the 20th century, which is still very much with us, diminishes these abilities over the period of learning. We need a new kind of school for the 21st century.

EDUCATIONAL TRENDS

From a consideration of societal perspectives, we turn now to an examination of educational trends over recent centuries.

Ancient legacy and modern trends

Trinity of education

There is a venerable tradition, extending at least from Jan Amos Comenius in the 17th century to Max Scheller in the 20th century of subdividing general education into three domains (see Pick online; Scheler 1958)[1]. This approach stemmed from the old tripartite notion of the human creature consisting of:

- a body that needs food and shelter, physical comfort, and fleshly pleasures, as well as other material goods and man-made things, available only in an artificial environment;
- a soul, suffering from solitude and searching for another soul, longing for sympathy and understanding, willing to give love and be loved in joyful communion with the universe; and
- a spirit, striving to orient itself towards the Initial Cause (Prime Mover, Life Source, Perennial Wisdom, Ultimate Truth, and Final Goals) of human existence, transcending all temporal and spatial boundaries.

The corresponding educational (i.e. cultural) domains have been designated by various words. In summarizing (very roughly) their essential meanings, we might call them:

[1] For a fuller account, see Murphy (1995).

- **Labour-technological education**, aimed at mastering arts and crafts, logic and mathematics, engineering, natural, social and behavioural sciences, and other activities enabling individuals to fulfill their needs and desires by efficiently processing, governing, and controlling matter, energy, and information in a world of objects and objective phenomena.
- **Communitive (interpersonal) education**, aimed at learning the ways and means of subjective-emotional relations and interactions between human beings (and, to a degree, non-humans). This can be done through ethical and aesthetic teaching, caring for those in need, playing games, dancing, singing, and story-telling; ritual and myth, folk-lore and philosophy, poetry and theatre, music and fine arts; discussing and solving problems of civic life, thus actively participating in public endeavours of social concern.
- **Transpersonal education**, aimed at the catechization and initiations of neophytes into the creed, mysteries, and sacraments of a particular religious confession or ideology; helping individuals to pose a question of their relations to the Absolute; or just endowing a person with a sense of belonging to something infinitely greater and more potent.

Diversions and estrangement within the educational whole

The so much talked about education-and-culture crisis (often labeled as the *Conflict of Two Cultures*, or the *Snow-Leavis controversy* – see Stange 1988 and Bissett 2002) has resulted, to a large extent, from the historical schism between the educational domains described in the preceding section. In the 17th century, Western Europe hailed the advancement of scientific learning and technological inventions, based on newly discovered mechanical laws of motion. Water-, and later steam- and electric-driven machines, self-acting and labour-saving, relieved man of gaining his daily bread by the sweat of his brow, and promised to turn his life into an earthly paradise. Believers in science and engineering did not foresee that the humanization of the machine would have the paradoxical effect of mechanizing humanity.

Rationalism backfired

Since the mid-19th century, we have witnessed the dominance of the rational and technological aspects of culture over the spiritual and cultural. Ironically, the rational domain has itself begun to suffer from the severing of its vital connections with the spiritual and cultural domains. The system of mass education –

one of the really miraculous inventions of that era, along with medicine – itself falls victim to the triumphant march of Reason.

Religion, philosophy and art, once so nourishing to humane values, have been made arid and sterile, incapable of counterbalancing and complementing rational and intellectual development. Meanwhile, the latter has encountered increasingly loud callings to fight against the proliferation of advanced technologies and even to penalize efforts to make new ones. This kind of debate has had led nowhere.

The 20th century witnessed, on the one hand, the highest degree of techno-scientific refinement such as, for instance, magnetic resonance imaging, among numerous examples. On the other hand, the 20th century also saw the creation of the most sophisticated devices to exterminate millions of defenceless people by, for instance, self-guided ballistic missiles with nuclear warheads. Examples here are numerous as well. Rationality, devoid of humane values, runs the risk of stagnating, or running wild, to our own destruction.

From schism to convergence

We need to envisage measures and take modest, practical steps toward restoring a lost balance and creative interconnectedness, which might be achieved by making each domain more perceptive and responsive to the true nature, needs, and aspirations of each. Perhaps the best advocate of such a convergence in the 20th century was the Russian philosopher Nikolai Berdyaev. Here are a few key points, extracted from his works, *Spirit and Machine* (1915) and *Man and Cosmos. Technics* (1990):

> The role of technology is two-fold. It has both positive and negative meaning.
>
> Technicalization dehumanizes man's life, while being in itself a product of the human spirit. But the relationship between spirit and technics is more complicated than it is usually thought of. Technology can be a force capable not only to de-spiritualize, but spiritualize as well.
>
> When obeying only the law of its own, technology would lead to the technicalized world wars and to an exorbitant etatisme, the absolute Supremacy of the State. The state gets omnipotent, even more totalitarian – and not under totalitarian political regimes only; it doesn't want to recognize any limits to its authority and does treat the man as his own means and tool.

Berdyaev's views suggest a healthy ground upon which educators of the labour, communitive, and transpersonal domains might collaborate productively. A hopeful future lies, not in the further adaptation of human personality to the machine, but in the re-adaptation of the machine to the human personality for truly noble, humane purposes.

Just as the autonomous nervous system liberates the mind for its higher functions, so the new technology can bring about a similar release of creative energy. To achieve this end, we must go beyond technicalities and tackle the more profound issues of education.

Liberal and vocational education

A false dichotomy

The rift between academic schooling and master-apprenticeship training goes back to the classical age of ancient Greece, when the liberal arts curriculum was originally designed as vocational education for politics. The first goal of such instruction was apprenticeship in the skills of rhetoric, in preparation for a career in political argumentation. At that time, the ability to do or to make something, and the ability to talk about doing or making it, were literally one and the same thing.

However, with the vast expansion of academic institutions since the early 19th century, rhetoric came to be seen as a means, not an end of teaching. As a result, rhetorical methods of academic vocationalism have been misapplied to a range of non-political crafts and skills which, to be learned effectively, need doing to be mastered.

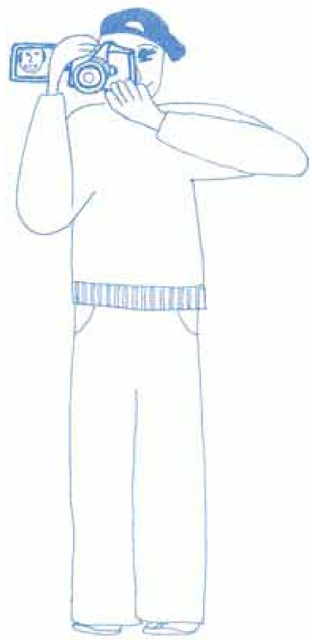
We believe that rhetoric, as a fully-fledged ICT-supported subject matter, could provide a collaborative community of practice built in the classroom. There, students, through assisted participation in rhetorical activity, could undertake what is now often called *cognitive*, or *semiotic apprenticeship*. That is, they could individually reconstruct the resources of culture as tools for creative and responsible social living in the classroom, the school, and the wider community.

A long time ago, distinguished voices were pointing towards this false dichotomy of technical and liberal education. Alfred North Whitehead entitled his 1917 Presidential address to the Mathematical Association of England *Technical Education and Its Relation to Science and Literature*. He wrote:

> There can be no adequate technical education, which is not liberal, and no liberal education, which is not technical: that is, no education which does not impart both technique and intellectual vision. [...] Geometry and mechanics, followed by workshop practice, gain that reality without which mathematics is verbiage. (Whitehead 1963)

ICT demonstrate that technical-vocational and liberal education can be taught together; they need not suffer from an impenetrable barrier between them. In vocational-technical education, essential knowledge and skills are transmitted, not by means of lecturing from a position of authority, but through a working interaction between master and apprentices. For a long time, vocational learning was looked upon as unquestionably inferior to academic instruction. Today, however, educators are reconsidering vocational learning as a useful basis for schooling.

Smarter people for smarter machines



We can sum up our argument so far by offering three points:

1. The post-industrial mindcraft economy and global society depend on smart machines AND a smart workforce, using high-end technologies with even greater competence.
2. Training and skill enhancement are part of a lifelong learning process.
3. Adolescent schooling, techno-vocational education, and actual work need to be interrelated. These truths apply to technologically advanced societies and to developing countries alike. Indeed, nations moving from ancient to modern agrarian economies must be even more prepared for the accelerating pace of change, because their youth will have even more to learn and master over their working life span. Befriending ICT in the initial stages of education will help young people come to terms with what lies ahead.

The only true education

Our aims as educators must go beyond specialized training of craftsmen or factory workers. The only true education is one where all arts, crafts, sciences, and technologies are linked and facilitate mutual cognitive development, productive creativity, and personal growth. The *new literacy*, a term used more than a decade ago (Anderson 1993) to embrace the changed literacy demands resulting from the new technologies in schools, and ICT offer educators, perhaps for the first time, an opportunity to create such an ambitious scheme.

The question is how can we create both the educational framework and the technologies to carry on a project of such proportions?

Continuous educational development

We need to build a continuing mechanism for the uninterrupted development of new curricula and new modular courses in an increasing variety of different learning environments. Furthermore, this needs to be extended from earliest childhood education through to adult education. Deep questioning is taking place regarding general schooling in our society:

- What should a student be required to know and do to succeed in the 21st century?
- What should a teacher be required to know and to do to help students acquire the desired knowledge and abilities?
- What role can ICT play in helping both teachers and students perform these new tasks?

New activities to be learned and new learning activities

Memorizing is not enough. The old pedagogy was justly criticized for presenting content in lecture format, as a series of abstract notions and formal rule-following to be memorized and reproduced by a student orally or in written or behavioural form. In many schools, little has changed. Much teaching is still conducted on this basis, while insufficient attention is paid to learning strategies (the tools and procedures a person uses to learn). A small percentage of students (those usually called bright or gifted, who are capable of building their own learning strategies) learn best under these conditions. However, most young people — and we would add, adults, too – need concrete, visualized, experiential, self-initiated, hands-on, and real-world learning opportunities. Yet many of these students are typically pushed aside and labeled *weak*, *poor* or *lagging behind*.

There is a movement in many countries, and within different education systems, to allow more variability and flexibility in the initiatives of individual teachers and local educational communities.

Changes are needed in the status and functional role of teachers. Contemporary teachers do not have to pretend that they know everything in order to formulate problems and ways to solve them. At the same time, teachers are taking on the increasingly important roles of advisor and learning facilitator. The new focus is on the process of learning and providing environments and tools that encourage everyone to become successful and responsible learners.

Three Rs for the 21st century

The new kinds of activities to be learned and new learning activities lead inevitably to a drastic revision of the idea of literacy, considered for many centuries the main goal of primary education.

The traditional notion of literacy (including so-called numeracy) was based on the Three Rs (Reading, wRiting, and aRithmetic), together with accurate handwriting (preferably calligraphic), and memorizing certain excerpts from textbooks and classical poetry by heart.

Now, we see an urgent need for a *new literacy* that is ICT-based and can be presented in three components corresponding to the traditional Three Rs:

- [Reading] – finding information by searching in written sources, observing, collecting, and recording;
- [Writing] – communicating in hypermedia involving all types of information and all media; and
- [Arithmetic] – designing objects and actions.

To sum up, we must reshape drastically both educational content and learning procedures. The new literacy shuns memorization of facts and rules. It stresses the ability to find facts and imagine unprecedented options. A capacity to understand and invent rules, posing problems to oneself, planning and designing one's own activities, come to the forefront. The goal of this kind of education is not a narrow technical fluency, but personal development alongside the core competencies for high-level thinking and acting.

Calling for new dimensions of teaching

Modern society needs educated citizens who can make decisions and implement them in a rapidly changing world. Individuals, organizational structures such as corporations and governments, and educational institutions, should be prepared for life-long learning. Information processing and communication are becoming major activities in daily life, and effective citizens and leaders of the 21st century will be required to understand and fluently use the latest sophisticated tools to manage an enormous amount of data, information, and messages. *Future shock* means there is an urgent necessity to solve unexpected or ill-defined problems. Therefore, lifelong learning will be the normal state for a modern individual.

One of the major changes in education can be described as a general shift from teaching to learning. This does not mean that the teacher is becoming any less important. Rather, the teacher's role is increasingly to assist students to become good learners. At the same time, teachers must help create stronger relationships between the subjects of study and concrete reality, putting them in a more relevant context for students. In many cases, this implies an integration of disciplines and cooperation among teachers of different subject areas.

Global awareness and cooperation

Educators all over the world have been working for decades to reform their local school systems according to their specific conditions, aspirations, and traditions. These educators are becoming aware that their local endeavours need the support of the global educational community to succeed.

Global awareness is greatly encouraged by the progress of modern information and communication technologies. ICT offer a wide array of materials for building new schooling systems that allow long-distance exchange and interaction between geographically spread groups of teachers and their students. These materials are flexible and responsive to the changing needs of learners of all ages.

Meeting this challenge, in turn, requires collaboration across national, cultural and institutional boundaries, and among individuals and groups who have been isolated. Electronic mail, bulletin board systems, teleconferences, and virtual communities on the World Wide Web (WWW) allow reciprocal communication among individuals and groups with common interests. Education researchers can team up with classroom practitioners to form research collaborations. Working together, regardless of where they live, scientists, teachers, and students are already finding once unimaginable freedom to investigate and understand powerful ideas that may have a global impact. A UNESCO-IBE document puts it this way:

> Current trends such as worldwide economy, the information technology revolution, the crisis in traditional ideological paradigms, massive migration, the growing concern with global problems such as the environment, drugs and AIDS, have modified not only traditional social relationships, but also culture's role in the development process. Two apparently contradictory trends dominate modern society, or, more correctly, many societies that are now in transit: standardization of cultural patterns and the search for basic reference points for cultural identity. The tensions, the imbalances and, in many cases, open conflicts have worsened to such point that some analysts estimate that future conflicts will take on cultural character…
>
> Education, both formal and informal, is at the centre of this renewal of methods for cultural dialogue. (UNESCO-IBE 1995, p. iii)

INFORMATION PROCESSING AS CORE ACTIVITY IN SCHOOLS

This chapter commences with a discussion of various societal perspectives – the accelerating pace of global change, globalization and ICT, and so on – concluding that radical changes in schools are needed. Next, we touch on key educational trends and suggest that a new literacy is required for the 21st century, calling for a different kind of teaching. The final section of this chapter argues that ICT can meet many of the major challenges of society and ultimately transform schools, as we currently know them.

Technologies and tools

As a wise man noted centuries ago, neither a bare hand nor an intellect alone can get jobs done. We need tools. And ever since the dawn of human history, people have been inventing and using tools – stone axes and hammers, potter's wheels and furnaces, levers, and pulleys – to process food and materials and to harness the energy needed for their physical survival and well being.

Similarly, people have used tools for information processing and communication exchange. The invention of language made our far-off ancestors capable of processing and controlling their own thoughts, feelings, and behaviour. Words can be considered as the tools of our mental activities, and the first and foremost of the latter is the activity of learning.

Until recent centuries, these activities have been manifested almost entirely through the organic functions of our minds and body (i.e. speech), and slightly supported externally by rather primitive tools and techniques (e.g. writing stylus and pen, or abacus). Then the printing press appeared.

During the 19^{th} and 20^{th} centuries, new tools for storing and transmitting information appeared. Today, computer-centred ICT are extending and amplifying our capacity for computational operations, logical reasoning, heuristic search, and grasping of coherence and hidden interconnectedness in chaotic signals and disparate data. That is, a computer is never autonomous but, rather, connected to a growing number of electronic digital devices, aggregations and networks for data and information acquisition, storage, processing, distribution and multimedia delivery. All these entities are subsumed under the generic name of ICT.

Educational technology of mind

We turn now to the educational technology of the mind, or an analysis of what is involved in learning. In most learning activities, the following phases can be recognised:

(a) Accepting and analyzing a problem.

(b) Making sure we have no ready-made solutions for it.

(c) Deciding to launch a project, setting the main goals and objectives, weighing our mental and material resources.

(d) Discovering that we are not equipped enough to cope with it successfully.

(e) Seeing what additional specific knowledge, skills, or experience we must obtain to arrive at a solution.

(f) Going through a corresponding process of research learning, training, drill and practice.

(g) Designing a set of possible solutions (generating options, comparing alternatives, evaluating), and then choosing the one that seems most suitable.

(h) Imagining what will happen if the chosen design is implemented. What changes will it make to our immediate surroundings and broader physical and socio-cultural environment? What consequences and side effects might it cause? How could we prevent, avoid, or repair them? Re-assessing the overall approach to tackling the problem.

(i) Reflecting upon what we have done: repeating mentally the road taken and actions made; describing the essentials; scheming about if, and how we could use our newly acquired knowledge, skills, and experience to address other problems in the future.

This pattern of learning activity phases, which we might call the basic educational technology of mind, can be developed and supported with various software, hardware, and courseware technologies of computer simulation, email networks, interactive multimedia, and other advanced uses of ICT.

Learning as information processing

Generally speaking, information is the content of all messages we receive from other people and the world at large, as well as those we originate ourselves and send back in exchange.

Information manifests itself wherever and whenever we find or create any patterns. A pattern is such a distribution of events in a time or space continuum that we can recognize and nominate, then compare to some other pattern and, finally, discern the former from, or identify with the latter. One may draw a parallel between the notion of pattern and the notions of order, organization, and form, as opposed to anything disordered, chaotic and formless; in this perspective, information can be understood literally as *putting into form*.

Human information processing – be it purely organic or instrumentally supported and extended by the most sophisticated machines – encompasses collecting, storing, retrieving, sorting out, assembling and disassembling, re-working, and transmitting patterns used in thinking and communication, as well as inventing, designing, constructing, and manufacturing any tangible object.

Any learning begins with seeking for, finding, and testing patterns – coherent clusters of information – favourable to our survival, comfort, and unfolding of our hidden potential. Even infants strive to explore their immediate surroundings by trial and error; they imitate adults' actions (e.g. smiling) and see whether something is edible, pleasant, amicable, hostile, or good as a tool to reach something desirable. The information gathered, interpreted, and evaluated during such explorative and imitative-reconstructive behaviour is stored in children's memory as mental models for their future purposeful actions, both physical and intellectual, including all kinds of consecutive learning endeavours.

ICT make natural tools in education because of the simple and fundamental fact that learning is largely based on dealing with information. Listening, talking, reading, writing, reassuring, evaluating, synthesizing and analyzing, solving mathematical problems, and memorizing verses and state capitals, are all examples of off-computer information processing. Even more importantly, ICT can be used for other types of information processing, previously marginal in the traditional school, but now becoming more and more essential, like project planning, or the search for new information outside school textbooks, as well as in the processes of so-called creative writing (drawing, constructing). In many other school activities (such as sport, for example), different kinds of interaction between students and teachers can gain from using ICT. The human dimensions of ICT manifest themselves in providing powerful means to open dialogue, fruitful interaction, and synergy between a teacher and a student or, rather, between Master and Apprentice, as well as among apprentices themselves – whether in close contact or by long-distance.

Historically, information processing and communication have been major school activities. These occurred mainly between the teacher and student with the very modest external support of pencil, paper, and chalkboard. Now, the extensive use of computers, with versatile sensors, peripherals and extensions, allow teachers a whole new degree of sophistication and flexibility.

2

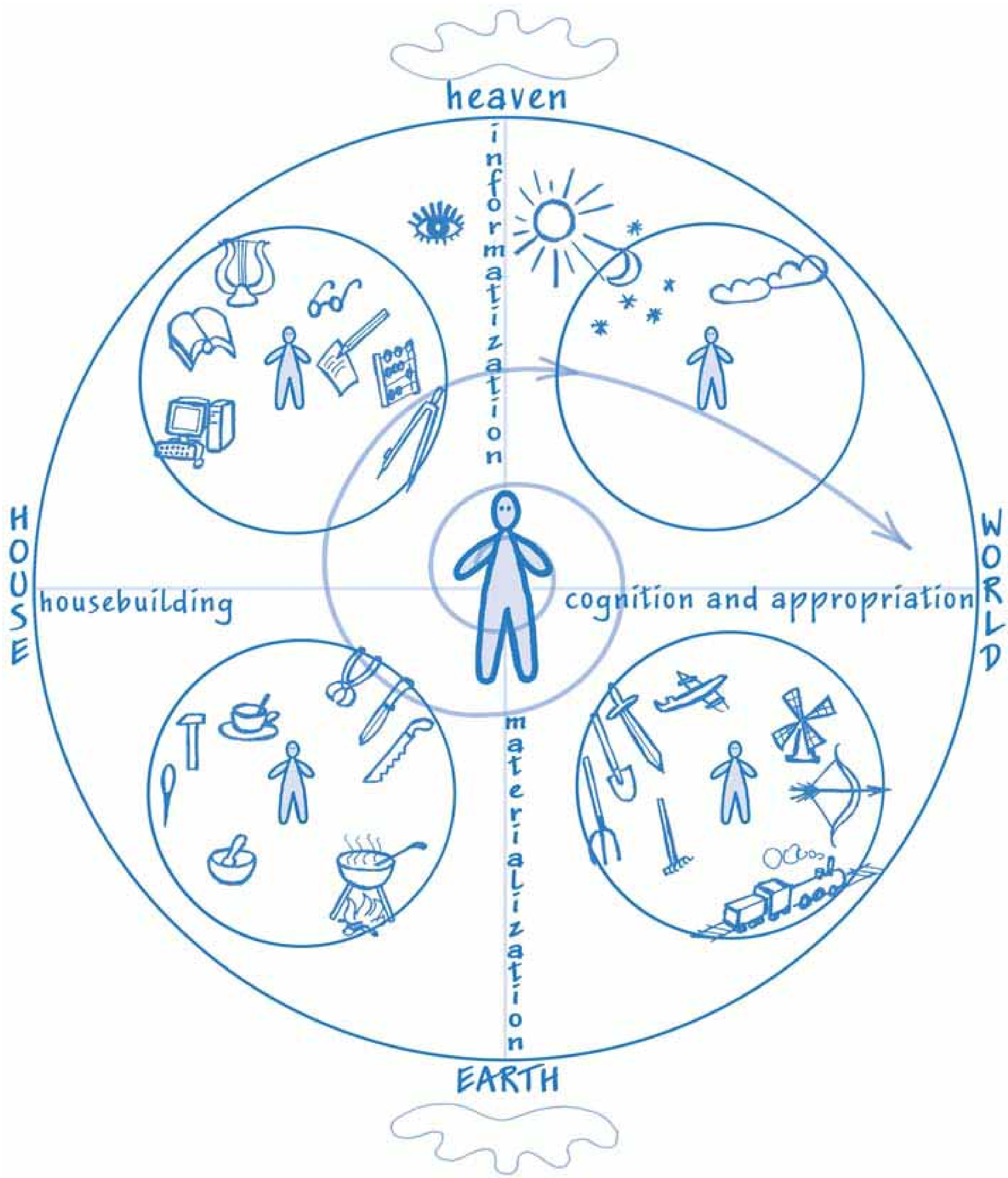
ICT: NEW TOOLS FOR EDUCATION

METAPHORS FOR COMPREHENDING ICT

A computer and its peripherals are often likened to an organism able to interact purposefully with its surrounding realities, which are perceived and modified through various receptors and effectors. This view helps to explain the principles of industrial robots, guided missiles, and similar automata, but the metaphor leaves out many other important applications of ICT.

One could also describe these complex hardware and software systems as sets of smart tools or, rather, as teams of highly disciplined, indefatigable, semi-self-governing artificial agents ready to execute strictly defined tasks. By wisely commanding, controlling, and managing the work of those tools or agents, we can increase:

- the sensitivity of our senses, which enable us to perceive events and communicate with other humans and machines over long distances;
- the amount of data, information, and symbolic expressions that can be processed and logically analyzed in a split second;
- the efficiency, accuracy and precision of our manipulations of both symbolic and material objects of the most diverse kind; and
- our capacity to make sound decisions based upon intuitive judgments and tacit knowledge.



Still another way to understand ICT is to imagine them as extensions of human organs and systems, including perceptive, reacting, thinking ones. These extensions operate mostly in the created (artificial or virtual) reality,, presented mostly by visual images. So we can use digital tools to clarify our inner picture of the outside world, as well as to enhance our ability to manage space and time while operating personal computer – a machine that works in permanent contact with a human. Co-ordination between the human body, our senses, and the personal computer is a critical issue in the effectiveness of using ICT. This coordination is similar to that required by other artifacts designed and targeted to human needs: tools for handicraft, furniture, eyeglasses, and many other material objects.

INFORMATION BASICS

In this chapter, we start with an approximate explanation of what an information object is and explain some basic facts about storing, transmitting, and processing information. After a discussion of the different types of information processing devices, we return to information objects and related learning and teaching activities in Chapter 4 and following chapters.

Information objects

Technology can provide our eyes with a static image (or picture) or a dynamic (changing) video image. It can also present us with an audio (always dynamic) sound. And both can be combined in video recording and playback. These are the basic types of information objects.

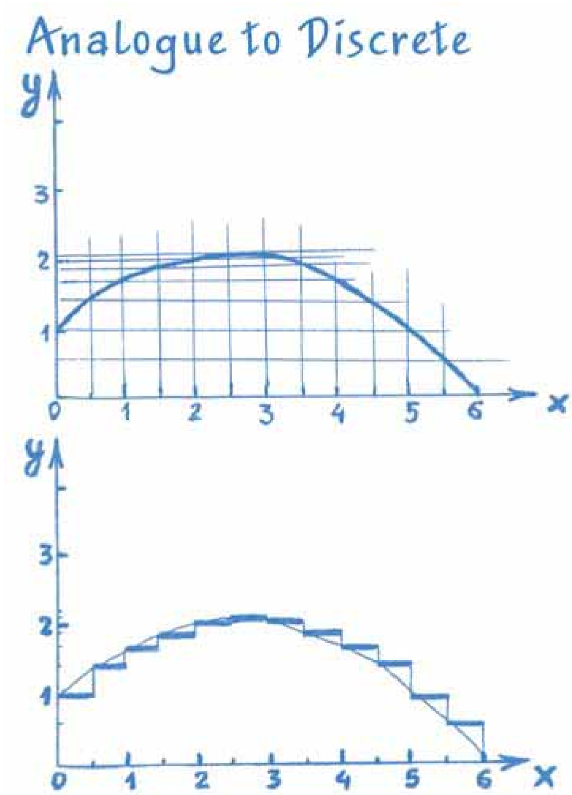
Humans can also structure information objects. For example, we invented languages and characters for their communication. Texts (sequences of characters) are formed information objects. There is also the possibility of making complex objects from simpler ones by means of links. A link is an imaginary connection, association, or arrow going from an element of one object (for example, a word, or a piece of an image) to another. The complex object constituted by such linked objects is called a hyper-object. ICT provide us with tools to transfer immediately from one object to another, or between hyper-objects.

Information space

As humans, we store a huge amount of collected information outside the human brain, in libraries and archives, and in other types of storage, and increasingly in ICT digital devices. These might include an individual, personal information space (like a personal library). Similarly, groups and organizations build their own information spaces. Thanks to the Internet, most of these information spaces are now parts of single global information space, in theory accessible to everyone.

Digital transformation

Signals and images in the physical world are either continuous or analogue. To be stored, transmitted, and processed by modern ICT, they must be transformed into digital, or discrete, signals. The simplest example of discretization is measurement. When you measure length, weight, or time, you transform an analogue value into a digital one: the result is a finite sequence of digits. In the following graphs, temperature is presented as a continuous curve. It is approximated by measurements in fixed moments, one an hour with an accuracy of one degree.



Words for big numbers

In the world of ICT, some very big numbers appear in measuring amounts of information, speed of transmission, and processing of information. To name these numbers in a human language, we need further words, and for this special Greek prefixes have been adopted:

K = Kilo = 10^3	T = Tera = 10^{12}
M = Mega = 10^6	P = Peta = 10^{15}
G = Giga = 10^9	E = Exa = 10^{18}

The same words are also used for powers of 2, exploiting the approximation $10^3 \approx 2^{10}$.

Storing information, memory and compression

When we store information (in a computer memory or in another way), we measure the needed memory size using specific units. To store the simplest piece of information, a '0' or '1', we need 1 bit. One byte equals 8 bits, and can store up to 256 different symbols – for example, the English alphabet (in upper and lower case), plus digits, and punctuation marks. Therefore, when we say that the memory size of a computer is 6 gigabyte, this means that the memory can store approximately 6,000,000,000 symbols. Bits are abbreviated as b, bytes as B.

In some cases, information can be compressed to occupy less space, and then de-compressed (decoded) to restore it close to, or often identical to, the original. Compression requires less memory volume for storage, and allows quicker transmission time. A popular format today for compressing video and sound is MPEG (in different versions: MPEG-1, MPEG-2, MPEG-4, and so on).

Here are some figures on the size of information objects given in orders of magnitude:

1 page of text occupies 1-10KB

1 picture of the screen of a modern computer of a good quality occupies about 1-10MB

1 minute of digitized sound of good quality occupies approximately 10MB (or, if compressed, with a minor loss of quality, it takes about 100KB)

1 minute of digitized video of good quality occupies approximately 100MB (or, if compressed, with a minor loss of quality, it takes about 1MB).

Transmitting information

Information is transmitted between people in different continents or inside the human brain in the form of signals. The signals are dynamic changes, or waves. Two major types of waves around us are: sound waves in solid, liquid or gaseous media; and electromagnetic waves transmitted in a vacuum (in any mediuma transparent for them), or channelled in a wire or optical fibre. The most important kind of waves is constituted by periodic changes (oscillations) in a medium. These periodic changes are transformed, distorted, reshaped or modulated, to transmit a signal. The frequency of the changes is measured in Hertz (abbreviated as Hz). One change per second is 1 Hz. In the case of sound, the frequencies that can be perceived by humans are in the range of 20 Hz to 20 KHz. In the case of electromagnetic waves, the frequencies used to transmit information are:

Visible light between 430THz (Red) and 750 THz (Violet)

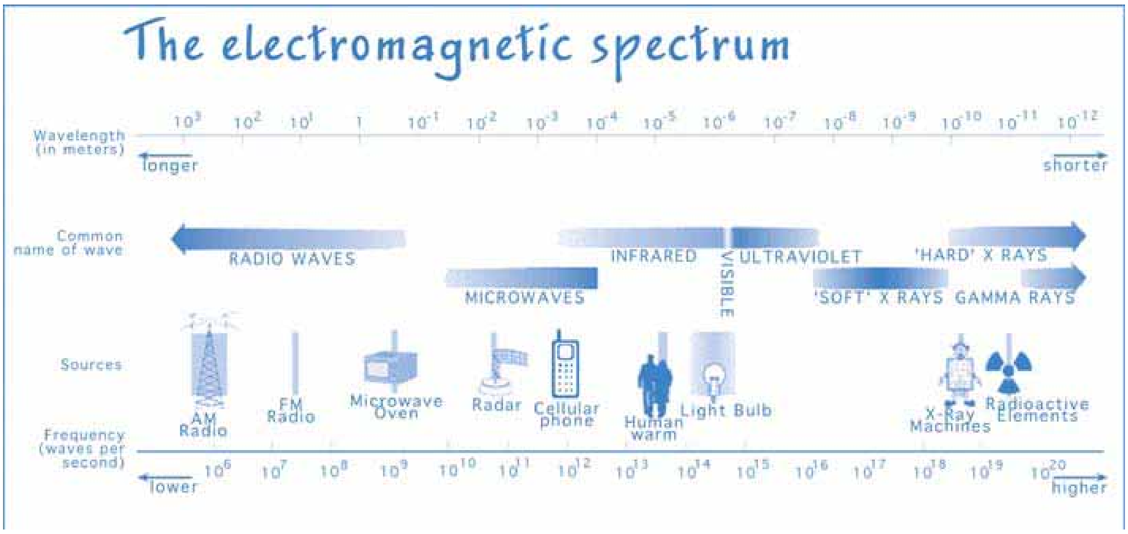
Radio (RF) in the range 100 KHz to 10 GHz (including frequencies for AM, FM, TV, cellular, and satellite transmission)

Microwave between 10 GHz and 1 THz

Infrared (IR) about 10 THz – visible light (Red)

Ultraviolet is visible light (Violet) – 100 THz

X-Ray is 100 THz

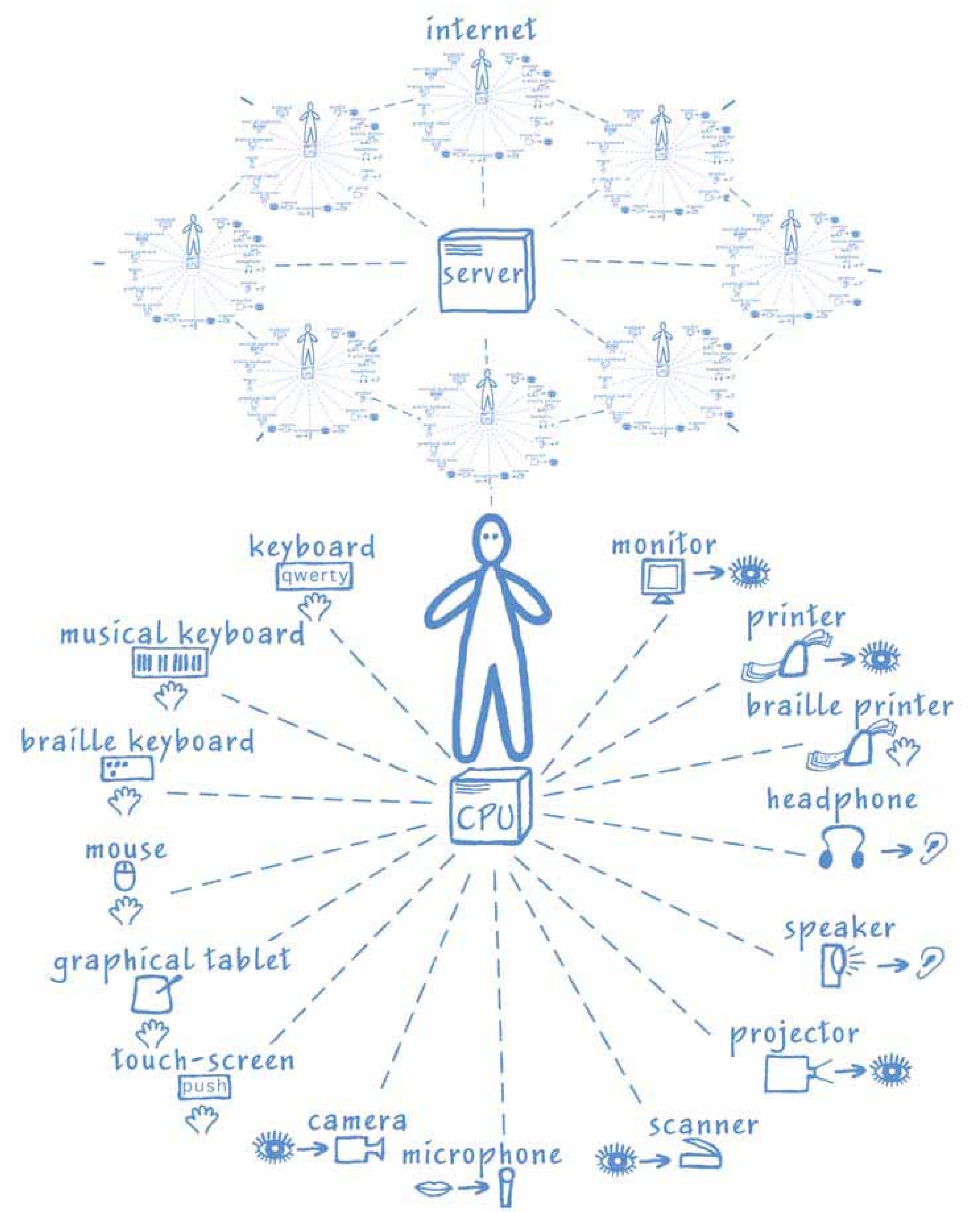


Visible light is limited by the physiology of the human eye. The limits indicated for visible light are not conventional but *natural* – starting with red and going to violet. Other borders are more a question of terminology.

In the process of information transmission, when modulating a wave of a given frequency, we actually occupy, not a single frequency for transmission, but a band of frequencies. With a wider band, we can transmit more information. In simple cases of wireless transmission, we cannot use the same band in the same geographic area for two simultaneously transmitted signals. Instead, we use higher and higher frequencies for transmission. For wired transmission signals in the RF range, we use in metal (copper) wires, while for visible light we use special plastic optical fibres.

HARDWARE COMPONENTS OF ICT

In this section, the focus is on what is termed *hardware* – the components of ICT like the computer itself, storage media, and input and output devices.



Computers

The computer is a universal information processor. In theory, any kind of information processing can be done on any computer but, in reality, this is not true. A specific task for a specific computer may require too much time, or the computer's memory may be too small. Computers process information in the form of electric signals. In other existing technologies, simple information processing can be done also in the form of air or liquid streams. There are attempts to produce computers that use light processing, or biochemical mechanisms similar to that of living organisms, but these approaches are at a premature stage.

CPU

Information processing is done by computer hardware. The most important components of computers are (electronic) semiconductors, similar to the components of radio or TV, but much more sophisticated. The number of electronic elements inside these components can be counted in millions. These elements are joined together to form integrated circuits (IC), commonly referred to as *microchips*, or simply *chips*. The core device in any computer, called the *central processing unit* or *CPU*, does all information processing. Today the CPU occupies a metal box in which you can see dozens of integrated circuits, wires, and cables connecting them. (Yesterday's computers were much bigger and occupied a full room, or even a whole building.) The main IC in the CPU is the processor itself, which does most of the active task of processing, including adding numbers, comparing strings of symbols, sending information to memory (see below), retrieving it from memory and, very importantly, reacting to signals from the outside.

The work a computer depends not only on its constitution as an electronic device, but also on the information stored in it or that it receives while in operation. This information can be considered as instructions that tell the computer what to do, and is called *software.*

Information is stored, transmitted, and processed in the form of strings of zeros and ones. The input of information into a computer usually involves the transformation of images or sounds into digital and discrete strings. The output involves the reverse transformation. These components of hardware and software responsible for these transformations and making them perceptible to the human senses, are called *interfaces*. Computer information is stored in special types of IC, called *storage* or *memory chips*. A computer's speed is an important factor in its performance. It is measured in MHz, which refers to the number of changes inside a computer that can take place in one second.

Monitor

An important component of any modern computer used by a human being (and for this reason called a *personal computer*), is the *screen or monitor*. Monitors not only display information but can also support direct interaction. For example, if you need to make a technical drawing of a particular detail with a computer, you move your hand equipped with one of many input devices (see *Peripherals* below), to create a line or activate a detail on the screen. The whole system of using physical movements to manipulate information and present this manipulation in intuitive screen images is called *graphical user interface* or GUI.

Connections

The CPU is connected with other ICT devices via communication channels. The most common communication channel is a cable plugged into a computer at one end, and to another device at the other end. The cables and sockets can cause problems, including incompatibility of sockets in the case of connecting your computer to a local telephone line abroad. A popular alternative to cables is wireless (radio-frequency or infra-red) connection. To simplify the graphic presentations, we do not include cables in the pictures, and say more about these connectors in the sections that follow.

Computer sizes

Computers that are placed on the desk of a clerk, student, or teacher are called *desktop computers*. Sometimes, however, the computer itself is placed under the desk with the monitor and keyboard on top. These computers usually weigh several kilograms, with the monitor usually being the much heavier component. Other computers are portable or mobile. Their weight and size permit them to be carried comfortably. Computers of a size and weight of a large notebook, which is easy to carry, are called *notebooks* (formerly, *laptops*). Today's notebooks weigh as little as 1–4 kg. Computers the size of one's palm, and weighing less than 1 kg, are called *palm computers*, *handhelds*, or *palms*. All such computers are called *personal computers*, or *PCs*, because they are intended for individual usage.

CPUs today are very small. We can say that for most school applications the size of a typical CPU is not a limitation. On the other hand, in some classroom situations, the size of the whole computer matters. If we place a monitor on a student's desk, it must be large enough to be comfortably visible, yet small enough to leave space for student work.

Energy for computers

Electricity is needed to run a computer and its related devices. The power consumption for a desktop computer is typically 100–500 watts. In many countries, this resource is widely available, but in others it is still a problem. For them, alternative power sources such as solar batteries, wind generators, and accumulators (rechargeable batteries), as well as UPS (Uninterruptible Power Supply), should be considered in the planning of ICT implementation. Solar batteries, for example, cost a few dollars and can supply a palm computer with energy, provided they are exposed to sunlight a couple of hours a day.

Portable computers can use the same power line as desktop computers. However, it is much more convenient to have a portable computer that can function, for a while at least, with rechargeable batteries. These can support the computer for a few hours, and then need to be recharged from a power source. In the best cases, recharging takes much less time than the computer needed to use up its power, and recharging can occur while the computer is in use. A bad aspect about accumulators, apart from their weight and considerable cost, is that, if used intensively, they last only a few months. Even in the best cases, a rechargeable batteries' life is much shorter than the life of the computer itself.

In many cases, the modern processors that have appeared over the last few years require more energy to run than the older ones. Roughly speaking, every action of the CPU needs a minimal amount of energy to be used. If the processor works faster, the same amount of energy is used in a shorter time. As the computer runs, this energy dissipates in the outside environment in the form of heat, and so computers come equipped with special cooling mechanisms like fans.

Peripherals

For the best utilization of ICT in education, a teacher needs a wide range of devices connectable to a computer, and these are referred to as *peripherals*. The major categories of peripherals are devices for:

- Input: alphanumeric keyboard, musical keyboard, microphone, tape-recorder, tablet and stylus, scanner, digital photo camera, video camera, sensors, and probes.
- Output: monitor, printer, projector, headphones, speakers.
- Control: motors, lights for robotics construction kit, and sensors.
- Communication: modems, communication lines, satellite and local network equipment, and wireless networks.

Having a wide range of peripherals for educational and general use is more important in a school than the number of computers. We consider these categories of peripherals in a little more detail in the sections that follow.

Different components of a computer as well as peripheral devices need to be connected via channels for information flow. In most computers today, cables do this, but wireless connection is increasingly possible as well, which then requires, of course, that the device has its own source of energy (usually, power line or batteries).

Storage

Information is stored in *integrated memory circuits* or *memory chips* in the computer's CPU. However, there are other ways to store information. These other means differ in capacity (the amount of information they can store) and access speed (how fast the information can be retrieved). Stored information can be retrieved and, in some cases, changed. Read-only memory (ROM) means that the user cannot change any retrieved information. In the opposite case, we talk about *rewritable memory*, stored on a computer's hard drive or on portable discs. The cost of storing information is constantly and rapidly decreasing.

The key storage devices currently are flash cards, magnetic tapes and discs, and optical discs.

Flash cards

Additional memory chips – so-called *flash cards* – can be easily inserted into and removed from the body of current computers. They do not require batteries to keep information stored. The capacity of one card today is in the range of 10MB to 1GB and access is fast enough for most applications. Flash cards are widely used in digital cameras (see *Cameras* below in this chapter) and other applications. They are rapidly replacing discs (see below). Some versions of ROM cards are used in game consoles (where they are also called *cartridges*).

Magnetic tapes

Magnetic tapes, similar to those used in tape-recorders, can be used for storing digital information as well. To read or write information on a tape, a special device similar to a tape-recorder is used, called a tape drive. The drive can be external to a computer or placed inside the CPU box. The capacity of a tape can be up to 10 GB and even more. Access speed, however, is slow, which can be critical for certain applications, though this is less important for most school uses. Magnetic tapes are rewritable.

Magnetic discs

The idea of disc storage can be traced back to gramophone recordings at the beginning of the 20th century.

Information on those discs was permanently stored in the form of small mechanical (geometrical) changes in the surface of the disc. Some of today's versions of disc storage use a magnetic principle similar to tapes, and these discs are rewritable. Discs with the capacity of about 1MB are also called *diskettes*; you can insert them into a drive (disk-drive), or remove them. It may take up to a minute for a computer to read from or write to a diskette. Newer discs have a capacity of up to 1GB. The competition from flash cards (see above) is strong. Discs with even greater capacity are mounted on their own drive, and these are usually called *hard discs*. Their capacity is in the order of 10GB to 1000GB. The access time for hard discs is fast enough for most applications.

Optical discs

Information can also be stored on a disc as an optical trace. This principle is exploited in *compact discs* (CD), widely used now for storing music. The capacity of a CD-ROM is approximately 1GB. Access speed may not be fast enough for some applications involving sound or moving pictures. To address this problem, observe the different speeds marked on CD-drives: 2x, 6x,... 48x... A newer form of CD-ROM is called *digital versatile disc* or DVD, which looks similar to a CD but can store 10GB or more information. Rewritable CDs and rewritable DVDs have appeared in recent years.

Human movement as input

The most common way to input information into computers is by human hand through a variety of devices: keyboards, the mouse, graphical tablets, and touch screens.

Keyboards

The most important input device for computers currently is the keyboard, which serves mostly for text input, and, to a large extent, imitates the keyboards of typewriters. The computer has many advantages over a typewriter, even apart from its more sophisticated software and other applications. The first of these is how easy it makes it to change, delete or insert any word or phrase. The next is the ability to copy any text fragment and to move it as a solid object anywhere within a text, or to another text, usually referred to as *cut-and-paste*. Touch-typing (not looking to the keyboard and using 10 fingers) is a useful skill in the educational context today. Students can learn touch-typing faster than handwriting; they can type faster than they can write; and the results are more attractive and much easier to edit and revise.

Extensive work with the keyboard, however, sometimes causes muscular tension and requires special precautions, which students and teachers rarely take (see the section below on *Health problems associated with computers*). Newer ergonomic keyboards are becoming more prevalent, as is the use of alternative methods of writing such as script and speech recognition. Different arrangements of characters on the keyboard could make typing more effective. A radically new tool, called the *Twiddler*, is an ergonomic handheld, touch-type keypad designed for chord keying, which means that like a piano you press one or more keys at a time. Each key combination generates a unique character or command. Because of resistance to change, widespread adoption of these tools does not look probable.

Keyboards of notebooks are usually built into the *book*. Keyboards are not usually built into palm computers. Sometimes a keyboard is represented by a screen image on which you type by touching keys with the tip of a special pen. Sometimes, lightweight unfolding keyboards are used for palm text input.

Musical keyboards

Musical keyboards look like a traditional piano or modern rock-group synthesizer keyboard, only smaller. Attached to a computer, this peripheral can be used far beyond the imitation of a piano. The standardization of digitized sounds of most instruments in MIDI (Musical Instrument Digital Interface) allows students to play and even to compose musical pieces performed by different instruments or an orchestra, and immediately hear a performance of the piece by those same instruments. Notes input with a musical keyboard can then be edited with a mouse. The avenues for students' musical self-expression are in this way dramatically enlarged.

Mouse and its alternatives

To manipulate screen objects, you need to *point*, *choose*, *grab*, and *open* them. In today's computers, these operations are usually done with a special instrument, which indicates an object on the screen and moves it as a solid body. This instrument is called a *mouse*, a handheld, traditionally grey, plastic body that you move on the table-top, which is usually covered by a small mat called a *mousepad*, designed to improve the movement of the mouse. As you move the mouse, a small object (an arrow, for example), called a *cursor*, moves on the screen, mimicking the mouse's movements on the table. The mouse has buttons that help you to extract, pick up, and manipulate objects. You move the cursor to an object and click a button; the object now is attached to the cursor and can be moved. If you click another button, the object *opens up*. These actions are part of GUI or the graphical user interface.

There are other devices to transform movements on screen into information manipulation inside the computer similar to the mouse. They all act similarly, but the physical movements of a human hand working with them can be quite different:

A handheld mouse, not lying on the table, can have a small gyroscope inside, and is useful when you show something to others on a big screen.

A *trackpad* is a small panel (about 3 by 4 cm) over which you move your index finger to control the cursor.

A *trackball* is a ball about the size of an egg embedded into a panel, which you can rotate.

A *joystick* is a small lever (as in a car transmission gearshift) used mostly in computer games.

There are also very small joysticks inside some keyboards called *trackpoints*, which you can push and deflect with your finger. These are also used as the mouse part of the Twiddler mentioned above, where the trackpoint is controlled with the thumb.

Wireless mice that have no moving parts are more reliable and have become more popular. Among them there are handheld mice that you do not place on a table but move in 3D space.

Graphical tablets

Another type of input is to draw or write with a pen. The difference between a computer pen or stylus and an ordinary one is that the computer pen moves over a special surface called a *graphical tablet*, and the trace of the move can be represented on screen. The computer can also measure levels of pressure. With appropriate software, a computer can imitate almost all existing drawing techniques and create some exciting new ones. The computer is very useful for technical drawing – now, mostly part of computer-aided design or CAD.

Handwriting

The most effective way to start written communication for children (and adults) is to have them type on a computer. But handwriting is still a popular and useful skill. Consequently, handwriting recognition, which immediately transfers handwriting into block letters on the screen (and text in computer memory), is a valuable supplement to keyboarding, and sometimes a major input technique (for example, in certain kinds of environmental observations). With palm computers, you can write text that can be recognized by the computer using a special stylus. Handwriting and drawing by hand on a large whiteboard can be done with a computer also. In this case, you write or draw on the board with a special marker that is traced by an infrared or ultrasonic detector.

Touch screens

The devices discussed above are intuitive enough but nevertheless separated from the objects on a computer screen. Another promising type of device combines seeing with touching, allowing you, for example, to outline an object on the screen with your finger and then move it to a different position with the same finger. This is already achieved with touch screens. A finger cannot indicate a very small object on a screen. However, this limitation can be relaxed by using a *stylus* on the screen (a kind of pen or pencil designed for this kind of interaction). Touch screens can work well and are more intuitive for small children, but are not widely used. One reason for this is their cost, which is higher than an ordinary screen and mouse. Nevertheless, they are the most popular devices in most information kiosks and in palm computers.

Further options for human movement input are discussed below under the sub-section on major trends in ICT.

Visual input

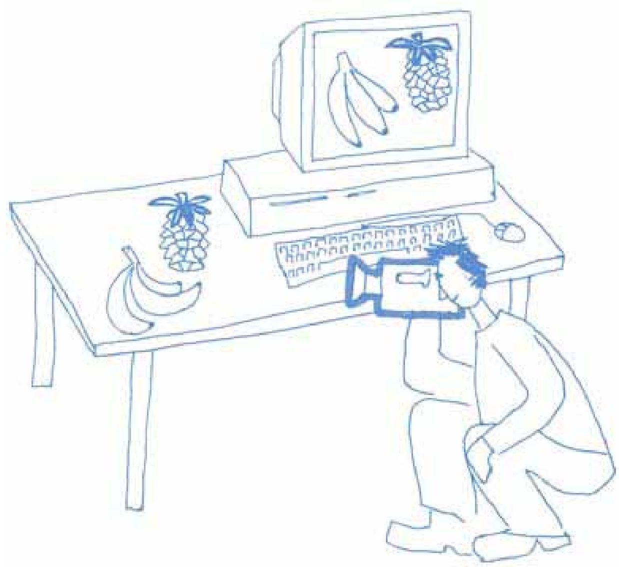
In the mid 19th century, photography was invented as a means of fixing and storing visual information in an external medium using a chemical process. In the 1930s, devices were introduced that transform visual information into electronic form for immediate transmission via electromagnetic waves: TV technology. In the 1950s, simultaneously with computer technology, methods to record and play back analogue TV and still images appeared: the videotape. At the end of the 20th century, digital photography and digital TV became an integral part of computer-based ICT.

Cameras

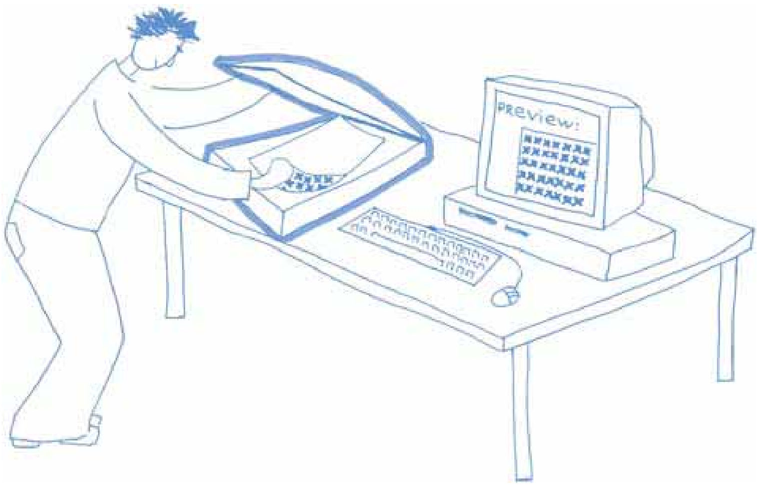
Cameras store or transmit visual images. The photographic camera stores a still image on photographic film for further chemical development. Instead of putting an image onto a film, a *digital camera* places it in the computer's memory, or in the memory of the camera for transmission to a computer for storage or direct printing afterwards. An interesting application of digital cameras is the projection of a small image (such as a bug, for instance) onto a large screen. Nowadays, digital cameras can store video images also.

Scanners

Scanners look very like copying machines, but are smaller and usually work more slowly. Instead of producing a paper copy of an image, a scanner transmits an image in digital form to a connected computer. Scanners can be used to transform information from a paper source – a text, an image from a book, a drawing, or a photograph – into a digital image. Additional devices can be used for scanning 35mm slides. There are also handheld pen-size scanners that you can move over a line of text or a bar code for input or storage inside the scanner. Special 3D (three dimensional) scanners can produce scanned images viewable from different angles.



Optical character recognition



A special situation occurs when an image is a text (or text combined with graphics) in printed or handwritten form. In this case, the image of the text can be transformed (converted) into a computer text file that can be processed as one does other texts in the computer (e.g. insert a phrase; change a shorter name to a longer one, and so on). This process of transformation from picture to text uses sophisticated software called *Optical Character Recognition* (OCR).

Aural input

As with visual information, non-electronic, that is mechanical technologies, were developed first to store sounds. Then, electronic technologies were developed to transmit sounds (telephone, radio), followed by electronic media and tools to store sounds (tape-recorders).

Microphones

Microphones transform sounds into electric signals for storage or transmission. There are different types of microphones and different ways to work with them:

- A microphone can be fixed in a stand in front of a speaker who is standing or sitting.
- Speakers can hold a microphone in their hand.
- A lightweight microphone can be attached to a speaker's clothes.

Information converted by a microphone into electrical signals can be transmitted via a wired or wireless channel to other devices.

Sound recording

Sound can be recorded with a usual tape-recorder. To process sounds with a computer, you need to convert them into digital form. A microphone can also be plugged into a computer directly. In this case, the computer serves as a recorder. Digital recorders to store sound in digital form using flash cards are becoming increasingly popular. Modern computers can easily store hours of speech. Music recordings, processed and compressed by computer (in MP3 format, for example), occupy very little memory. The spread of this process, on CDs and through the Internet, is changing the recording industry and affecting mass culture.

Speech recognition

During the last few years, software has been developed that allows a computer to transform human speech into a text file similar to the conversion of handwriting as discussed above. This transformation can be done with a level of quality that makes it adequate for educational applications, and is useful, for instance, in learning English.

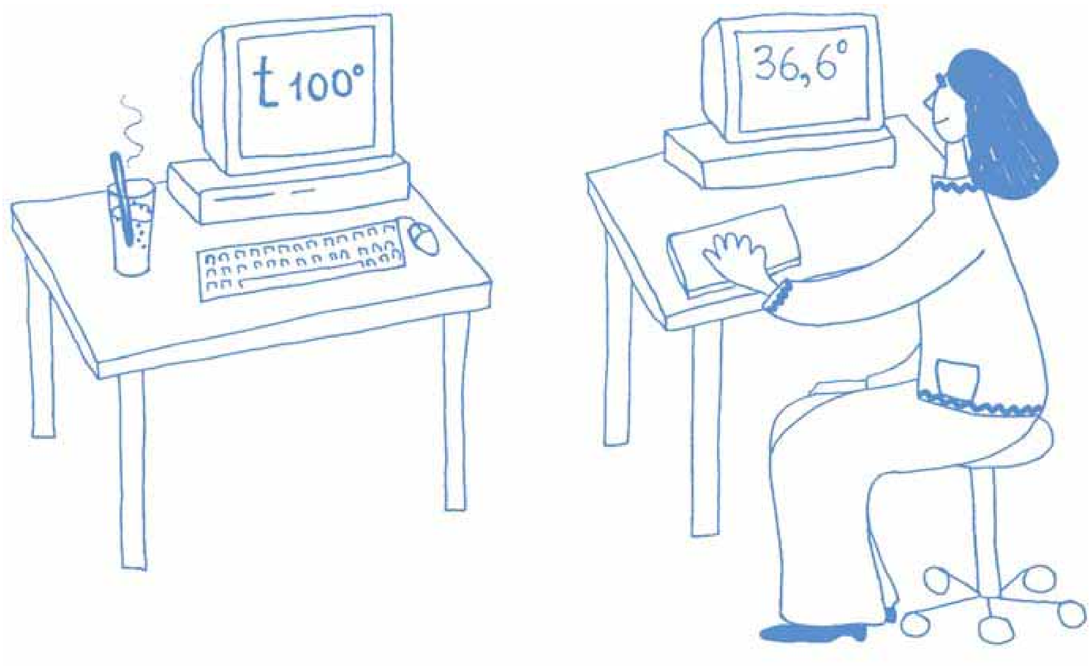
Sensors for input

Measurements of the environment like temperature, humidity, acceleration, or magnetic field, can be input to a computer-linked device called a *sensor.* A sensor generates an electrical signal that is then usually transmitted to a computer via an interface.

More sophisticated sensors can measure such parameters, store, and display them, even if a sensor is not connected to a computer. This can be done by individual sensors or by what is called a *data logger*, a special device or small box to collect and store data. The content of measurements can then be transferred to a computer. Very promising in school education is the growing number of sensors – from those that measure acid rain and heavy metal oxides ratio in potable water to the Global Positioning System (GPS), which allows anyone to find geographic coordinates and related information on the earth's surface.

Output

Output refers to information that a computer sends to a human user, or, sometimes, to other technical devices.



Visual output

The most immediate computer output is a visual image on the monitor screen.

In most computer applications, the image on the screen is discrete, and consists of millions of picture elements called *pixels*. The colour and brightness of each element appears as a combination of three colours called *RGB* for red (R), green (G), and blue (B), with varying brightness for each colour. In reality, for every particular screen, each of these three basic colours consists of the entire spectrum of light waves. The brightness (intensity) of the three basic colours is coded by a symbol from a finite range. The symbol and the range of old computers were just one byte (8 bits). Today, colours are usually presented by 3-byte coding (24-bits) representing millions of colours) or 4-byte coding (32-bits) representing billions of colours. The latest technology appears to be able to capture all possible variations in colour. In normal light conditions, the human eye can recognize differences in brightness (contrast) in the range of 1:10,000 or even more. Existing output screens can provide differences in brightness up to 1:1,000. In many cases – in most school conditions, for example – ambient light reduces the contrast radically, and so teachers need to adjust conditions of vision and the absolute brightness of screens. The optimal brightness of screens lies in the range of 50–400 Lux.

Resolution (the number of pixels in rows and columns) is usually named by acronyms such as SVGA (800x600) and XGA (1024x768). The ratio of the two factors is 4:3. The resolution is limited by characteristics of the screen, but mainly by a computer's power to *refresh* images quickly, which is needed to make visualization of the processes adequate and the computer-human interface smooth. XGA is the most widespread resolution in use today but higher resolutions called SXGA and UXGA are coming.

TV screens similar to, or the same as, computer screens used today, offer a slightly different way of presenting information – partly digital, partly analogue. Generally, today's TVs produce less detailed images than good computers, though the newest TV standards have images of the same quality as good computer images. This improved definition is called *HDTV (high definition TV)*. The move to HDTV is accompanied by a trend to change the aspect ratio (the fraction of screen width to its height) from 3:4 to 9:16, which is the ratio usually seen on cinema screens.

Theoretically, the limits of a visual image are the limits of human perception, which means that the screen can provide all the colour and brightness variations in the smallest details in the visible field (and even pay attention to two-eye stereoscopic vision). In reality, existing screen images are somewhat more limited: they have less detail than the human eye can grasp. The human retina has about 300 million cells whereas the best screens today have about 10 million pixels. Eventually, there is a natural limit to the improvement in quality that the human eye can perceive, which will occur when the computer screen is large enough to cover the prime area of clear vision and, at the same time, the smaller pixel-like details are no longer seen separately.

Of course, further improvement can help in some applications. For example, a graphic designer can look at a large screen containing a larger image, and then move in closer to look at a detail. That kind of situation can be covered by the standard zoom options of software systems.

In some countries and regions, there has been concern over monitor safety. This problem has two aspects. The first is image quality. Older monitors (especially, bad quality TV sets that are sometimes used as monitors) have a blinking, non-stable image, and can cause considerable eye tension. The second issue is the radiation (mainly, radio frequency) that the monitor emits. National and *de facto* international safety standards have been established. Presently, monitors are as safe as possible, especially in combination with other proper conditions such as attention to ambient light. One of the key parameters of image quality is refreshment rate, which by most standards, should not be less than 85 Hz. In many newer computer models, it is about 100 Hz.

The classical display technology is the cathode ray tube (CRT), used in most TVs as well as in most monitors. This device is limited by its large depth-dimension and weight. A safer and more comfortable alternative is the LCD (liquid crystal display) monitor, which takes up much less space on a desk, and is important for many classroom applications. They are more expensive than CRT monitors today, but the prices for a whole computer system are not dramatically different.

Projectors

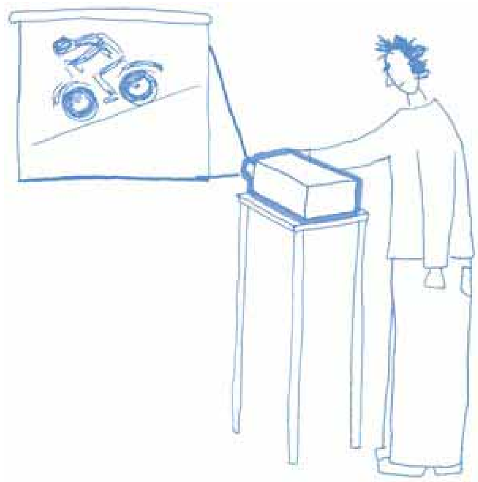
Computer images can be projected onto a screen. The beginning of projection traces back to the centuries-old *Laterna Magica* and Shadow Theatre. Projection flourished in the cinema era. Pre-electronic projectors used transparent film with an image to be projected. The 35mm film can be used in a roll as in dia-projectors (almost non-existent today), or cut into slides for use in slide projectors. Today, all slides (or screens – information objects to be projected) can be made on computer or be input to a computer and presented on computer screen. Special software used for projection of screen images, constructing, and organizing them is called *presentation software*. One of the popular software products here is Microsoft's PowerPoint.

Electronic technology has made it possible to project computer-generated images as well as images from a camera and from a VCR (video cassette recorder). The projected images, different from a computer monitor or TV screen, can be of any size. The only limitation here is that the brightness of the image is reduced proportionally to the area (or squared linear size) of the image. If the ambient light in a room is stronger than the projector's light, differences in colour and brightness of different parts of the image on the screen are not seen clearly enough or, in some cases, at all. The projection device is usually called a *multimedia projector* or *LCD-projector* (indicating, not in all cases correctly, the technology used), or beamer.

Projector technology has developed affordable solutions that are available now in many schools. A computer presentation or video image can be brought to any classroom using a portable screen (weighing less than 2 kg), a portable projector (less than 2 kg), and a computer (less than 2 kg). In fact, each of the items can weigh less than a kilogram.

One of the important trends for monitors and projectors is standardization of the digital interface between computer and the device. The *DVI (Digital Video Interface)* standard describes the digital interaction between monitor and computer.

Stereovision



The ability to see with two eyes is important for human perception in some cases. For example, stereovision is useful to estimate distance along with other instruments like accommodation, head movements, and relative size of objects. Accordingly, it is possible to improve perception on a computer by creating a stereoscopic output. This can be done with separate screens for each eye, or by showing on the screen alternating pictures for each of the eyes. Closing screens for eyes alternately can solve the problem of showing to each eye what is needed. The closing can be implemented, for example, by glasses in which the lenses are made out of liquid crystal and become transparent and opaque alternately.

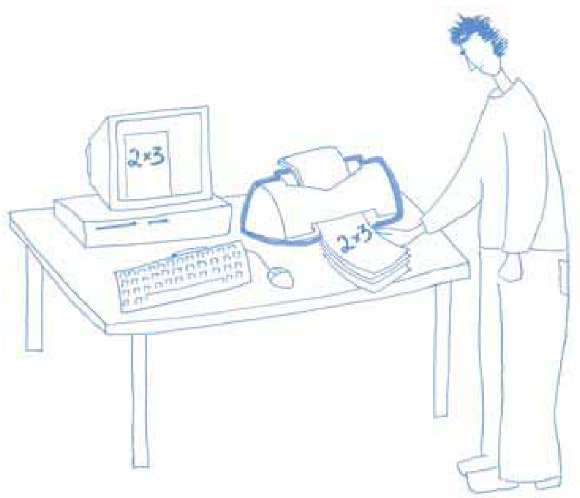
Printers and plotters

A printer transforms screen images into images on paper, so-called *hard copy*. A natural consequence of this is a need for paper and ink. The problem of cost here can be serious for schools in particular, because it is so easy to generate printouts in large quantities.

Laser printers produce black and white images and text of good quality for all school applications at an affordable price. In fact, laser printers changed the appearance of the world of written text. Once, the quality of print correlated with the respectability of the author but this is no longer so since, at first glance, all printed papers look the same. Alternatives to laser printing are *LED (light-emitting diodes)* and *ink-jet printing*. These printers are used in schools as well, but do not provide any considerable advantage. The generation of printers before laser printers were so-called *dot-matrix printers*, which used principles similar in some respects to old typewriters with printer ribbon and mechanical impact. Dot-matrix printers are useful if a school has poor quality paper or if you need to use wider paper or long rolls of paper (for banners, for instance).

It is desirable also to have *colour printers* in schools. A little while ago, the price of colour printers and supplies was too high for most schools but, in recent times, the situation has changed and colour printing has become much more affordable.

A recent invention in printers is so-called *Random Movement Printing Technology* (RMPT). Printers using this technology can be the size of a computer mouse and used in the same way: randomly moving it over a sheet of paper of any size leaves text printed on it.



A device similar to a printer in its functionality, but based on a different technology, is a *plotter* in which an image on paper appears, not as a combination of dots, but as a continuous line of ink.

Audio output

The audio channel is under-exploited in modern ICT in comparison with the visual channel. An important aspect of aural perception is locating the sound source using bi-aural (stereo-phonic) mechanisms. Two loudspeakers of mediocre quality are the most widespread audio output for consumer computers. Headphones can be used for stereo output as well. Some are better than others in quality of sound and the level of blocking of outside noise. Headphones can provide better quality than loudspeakers of the same price. In general, headphones are more useful for schools than speakers. Headphones can be coupled with a microphone.

Control

Control applications were among the most important applications of ICT before the advent of personal computers. Among specific cases are control of industrial machinery, power plants, and missiles. By contrast, personal computers mostly control output devices like printers. However, even this situation is changing, since a personal computer can, for example, be the control centre of an *intelligent house*, where the owner instructs the computer to operate all home appliances.

Communications

The real power of computers comes with linking them together, and in this section some of the key ways of doing this are described.

Communication channels

As noted above, computers are connected to other ICT devices by communication channels that can be wired or wireless.

In general, wired (cable) connection remains the more common type of connection. A cable connecting a computer to a peripheral can be used for three purposes:

1. to transfer energy (electrical current) to a peripheral;
2. to transfer control signals to and from a peripheral (for example, a printer can receive a command "start printing", and send a feedback "not-ready", or "start sending the image to print", or "out of paper"); and
3. to transfer input or output information (text to be printed to a printer, or sound to be digitized from a microphone).

It is common to transfer different electrical signals through one cable in several separate wires. (Actually, the same wire can be used for many signals simultaneously as well.) For different channels of communication, different cables are used. When we connect a cable to a computer or peripheral, we use *sockets*, sometimes called *ports* or *plugs* in the computer's box.

A crucial issue in the use of cables is standardization. Travellers, for instance, know well that about a dozen power plug standards exist internationally and perhaps a hundred telephone plug standards. Fortunately, standardization in the computer world is becoming more prevalent. At the same time, manufacturers are producing more and more new sockets. Consequently, when connecting a computer to external (peripheral) devices, one must be aware of such labels as PCMCIA, USB, IEEE 1394, and DVI.

An important characteristic of a channel is the speed of transmission it allows. For some applications, including school ones, it is also important to plug in or unplug a peripheral device while the computer is working. Old interfaces often required the computer to be turned off while you plugged in or unplugged a device. The newer USB interface does not require turning off the computer while connecting a new device.

After decades of experimenting, wireless connections have become more and more reliable and popular. Using these channels can be critically important for schools, because they provide much needed flexibility. A channel allows computers to be moved between classrooms while keeping the network still operating. In the classroom, it allows children to sit where they are most comfortable without having to struggle with cables. Wireless connections can still be used between keyboard and computer. Brand names like Bluetooth, Airport, as well as standards of Wi-Fi (wireless fidelity), or IEEE 802.11, are used to describe common wireless interfaces. Wireless communication, however, has its limitations since, for example, infrared connection works well in a direct-sight situation only.

Networking

Computers linked to communicate and exchange information constitute a network. The most common standard of communication via wired local area network (LAN) is IEEE 802.3 (*Ethernet* is another name). It can be wired or wireless.

Sometimes a single computer called a *server* is dedicated to information storage and exchange for a network. Other computers are *clients*. Often, computational and storage power are concentrated in the server, and client computers are made as simple as possible. Such clients are called *thin clients*. These computers have few precise mechanical works (spinning discs) and a small and cheap display that is hard to break and easy to replace.

In the school context, relatively primitive computers can be useful when all that is needed is basic text processing. It may then be sufficient to have just a keyboard with simple electronics, small memory, 4 or 8 lines of LCD and interfaces. The *thin computer*, also called a *thick keyboard* or *smart keyboard*, consists of a keyboard extended by a minimal display device to see what you are typing, and has a limited memory, an interface to transfer your text to a server or a printer, a processor to manage all of these, and a power supply (usually an inexpensive accumulator battery).

Internet

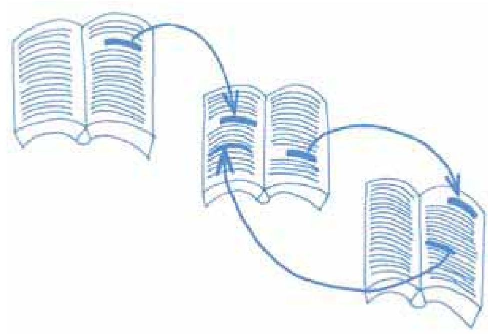
The next natural step is to link or network separate computers. Two computers can be linked via modem but this process is expensive if the computers are really distant from each other. We may compare this computer linking with the courier mail of the past, where a messenger brings a letter from one point to another. The high cost of this form of communication was reduced by the modern postal service. Developers of the Internet (known also as the *Net* or the *Web*) thought similarly that having electronic post offices functioning automatically in many places would cut the costs of individual communications radically. As with ordinary mail, one can move bulk mail between two major post offices in two cities as well as deliver individual letters locally. In the computer world, this is called *email*, and it was the starting point of the Internet.

Several important features contribute to making the Internet the most democratic information medium today. Besides sending and receiving electronic mail, the Internet provides an opportunity to place an information object (however complex and possibly linked to other objects) on a computer, give it an address, and make it available to a range of users who are also connected to the Internet.

Hundreds of millions of people in every country of the world now use the Internet. A popular way to communicate over the Internet is to post information (usually text or pictures) to a personal or business *homepage*, or *website*. Another Internet feature is *user-groups* who have access to *bulletin* boards – a collection of information on a specific topic that can be read and extended by members of a specific group with access. Emails move so quickly – in seconds from any sender to any receiver – that they allow for an exchange of information *online* (staying Internet-connected, sending and receiving messages). This mode of communication is also called *chat*.

Today the Internet is the biggest ever network channel and source of human information. Over the last decade, the Internet has grown exponentially in numbers of participants and in the amount of information available. Access to the Internet is possible, not only with the average personal computer, but also with simpler equipment called a *network computer* (a kind of thin client), which has an Internet resource and connection but without computer software and storage. A TV set with a simple device like a Nintendo-SEGA game machine can be adapted to provide access to the Internet. So can an enhanced telephone set.

Videoconferencing



The idea of combining telephones and TV communications has been tried for many years. The principal problems have not been so much technical as organizational, to do with infrastructure (allocating channels), and economic (it has been extremely expensive). In the last decade, however, computer algorithms and standards of compression, as well as channels of communication, have improved greatly. A roving video camera attached to a computer can automatically focus on a person speaking. Participants have microphones mounted on their desks and when they ask a question, the camera moves in to film them, and the image is displayed on a monitor screen. A human face and figure, slides, video, Internet, whiteboard writing and drawing can all be seen on-site or transmitted via the Internet. The result is an instant multimedia presentation.

Channels for distant communication

For most educational institutions today, telephone lines and modems are the usual communications media for connecting with the Internet. The speed of information transfer via telephone lines is usually below 56 Kbps (if the fre-

quencies used are the same as for voice transmission). It is possible to transfer data and pictures and even low quality, live video signals via such channels. Telephone lines can also be used to transfer radiofrequency signals to make transmission much faster, which is the technology used in *digital subscriber lines* (DSL). An alternative is a radio channel via air (amateur short wave or another radiofrequency band, for example 2.4 GHz). An example is GPRS (General Packet Radio Service), a standard for wireless communications that runs at speeds up to 115 kilobits per second. Satellite communications in GHz bands are among the most rapidly growing new ICT media today. When the rate is fast enough to transfer an acceptable video-audio signal, it is usually described as a *broadband* channel (starting from 300 Kbps). Optical fibres with much higher frequencies provide broadband connectivity.

DIGITAL INFORMATION RESOURCES

Information objects and their screen presentations

This section deals with different types of information objects and their screen representations, including instruments to operate with them (editors), and then moves to more sophisticated tools.

Graphical user interface or GUI

Early personal computers could not display graphics well. The only information objects to be displayed then were texts, arranged in lines. A profound breakthrough in the history of computing was the invention in the 1970s and its adoption in the early 1980s of what is called *graphical user interface* or GUI (Apple's LISA, Macintosh, and, then, Microsoft's Windows). The difference in perception and understanding of an information object presented as a text, a table, a formula, or a computer program, in visual form can be dramatic. The ability to deal with an information object as something real – that is, a manipulable object – makes it even more powerful. Generally GUI allows you to use your eyes for information perception and your hands for actions over information objects.

Direct manipulation of graphical objects on the screen in a way that allows you to see what is happening is referred to by the acronym *WYSIWYG (What You See Is What You Get)*.

Desktop and window metaphor

In many computers, before dealing with any specific information object, you find the computer screen organized as a *desktop*. Several object names, called *icons*, lie on this desktop. You can move these and place them wherever you like. You can *open* an object, see its presentation (text or picture) on the screen, and work on it. Some of the objects are folders. Inside folders you find the names of other information objects – some of them are the names of other folders. Some of these are executable programs and you can start running them, usually with a graphical effect of the run seen in a *window* on the screen.

One-dimensional editing

Texts

From the birth of the personal computer, working with texts has been the major application of ICT. Soon it initiated a new culture of writing since text on screen turned out to be much more flexible and transformable than written or typed text. The technology influenced the psychology and social context of writing, which, in turn, changed technology.

Here is an example of how technology is changing the nature of text. In traditional written language, we may write, for instance, “see p. 56” or “compare Johns and Black, 1992”. In reference books structured alphabetically like encyclopedias, these references can be given also by a difference in font, as in “This work led to the teaching of *pedagogic anthropology* in the *University of Rome*." Here combinations of words in italics – *pedagogic anthropology* and *University of Rome* – refer to other sections or chapters, which can be found alphabetically, with explanations about pedagogic anthropology and University of Rome respectively. The action of looking for another page, or another volume of the same encyclopedia, or even another book at a different library, is very much simplified with computers: to find a reference or link, you simply click a button and you are immediately transferred to the desired pages, books and libraries. To create a link, you work in a text-editor in a natural and elementary way. The text containing these links is called *hypertext*. The links are sometimes called *hyperlinks*. It is more natural to call them simply *links*.

Sounds and musical tones

Recorded sound can be presented on screen and edited in the same way as any text.

A special type of sound is a musical tone. Here the sound can be composed, not only changed. The usual notes can be presented on the computer screen and used in a standard way. Notes can be represented in a more graphically intuitive way by height and length in combination with MIDI interfaces.

Video

Working with pre-recorded video-fragments, their cutting, sequencing in an arbitrary way, adding sound and special effects is now possible using ordinary personal computers. For children starting from an early age, this kind of video editing constitutes a powerful environment for their communicative development.

Timeline

A timeline of events can carry icons or pictograms, or other names linked to information objects representing events. In this way, a timeline is similar to time wall-charts. In these charts you can see the whole timeframe, with much more detail of events. The timeline can also be represented as moving in response to the cursor.

Two-dimensional editing

Images on computer screens are combinations of pixels, and so the obvious way to construct or change an image is to create it pixel-by-pixel. To make this process simpler, we can use a *magnifying glass* tool. Of course, in most cases, this method takes too much time, but it can be used in special cases to make minor changes. More often we use corresponding methods of editing images by:

- changing digitized photographic pictures, or
- making and changing different types of drawings.

Pictures

In the case of photographic images, the computer extends dramatically the set of tools and operations available: resizing, cropping, lightening, darkening, sharpening, and so on. In this way, photographs can be transformed quite professionally, and then combined in sophisticated ways.

Drawings

In computer drawing, there are two major options:

- Using a brush tool or pen tool.
- Using additional software tools similar to a ruler, compass, and templates.

In the first option, software and hardware were developed to mimic traditional techniques and introduce new ones. The second option, the computer version of technical drawing, has developed enormously, especially in the field of Computer Aided Design (CAD) – see below under *Three and four dimensional editing*.

Maps and multilayer images

One option with computer images is to have several *layers* for an image, which is helpful in an application such as editing maps.

A special kind of graphical design is the production of plans and geographical maps. Today this is done mainly in so-called *Geo-Information Systems* (GIS). Maps produced with GIS are examples of *multilayer images* that can be edited in each layer separately. Good GIS has sophisticated mechanisms to represent objects like rivers, state borders, and place names on maps in order not to overlap.

Three- and four-dimensional editing

Computer aided design

Computer Aided Design or CAD has replaced traditional drawing almost completely. CAD allows you to create a 3D object on the screen that you can then turn around in space or zoom in on to see in more detail.

Like pre-computer design, CAD systems:

- have developed in different directions, for use in architectural design, fashion design, machine construction (cars, aircraft), electronic design, and other fields; and
- use libraries of ready-made templates from particular professional fields, and multi-layer construction.

So-called *Computer Aided Manufacturing* (or CAM) is computerised design of the manufacturing process. CAD/CAM is a combination of two.

Computer animation

Sophisticated and expensive instruments as well as children's simple tool-kits can be used to create artistically impressive or scientifically precise and enlightening computer animations. More and more movie scenes are now produced in artificial settings with characters designed on a computer by means of special software.

Students' animations are usually simple and two-dimensional (flat). Adding a time dimension makes them 3D objects. Simple animations made by groups of students over several hours can be more educative for the creators and more exiting for the spectators.

Multimedia presentations

Tools are available to make and show sequences of static (still) screens of images. Screens can contain visual representations of various information objects: pictures, drawings, diagrams, tables, as well as important lines of text, visualizations of experimental data, and mathematical models. A sequence of screens constitutes a *slide show*. Such sequences can run autonomously, without a human operator, but are much more effective in association with live human speech. This is a so-called *multimedia presentation*.

Combinations of different kinds of output and different kinds of information objects are usually called *multimedia*. This term was coined in the early 1960s to denote the new synthetic genre of *avant-garde* artistic stage performances comprising action-painting, music, declamation, pantomime, slide-projections and dynamic colour lighting effects. In the 1970s, multimedia became the trade expression applied to joint enterprises in designing, producing, promoting and marketing best-selling books bundled with hit-movies of the same plot (or vice versa), accompanied by the film's music soundtrack, T-shirts emblazoned with portraits of starring actors, and other paraphernalia. The computer industry picked up this coinage in the mid-1980s and used it to describe hardware and software configurations able to run alphanumeric, graphic and sound processing sub-routines simultaneously. Of all technologies, computers are ideally suited to mixing or combining media.

Human-computer interaction and communication

Virtual reality and cyberspace

Cyberspace and *virtual reality* (VR) are perhaps the most frequently heard, and least defined, expressions of the digital era. The term *cyberspace* was coined by the Canadian science-fiction writer William Gibson, author of *Neuromancer* (1984), who fathered a genre of morbid cyberpunk novels. *Virtual reality* was concocted as a commercial brand name for a line of advanced graphic video games in the early 1990s. Both coinages stuck and became household words in media and computer science. Cyberspace connotes an informational space that is generated *inside* each functioning computer and spreads *outside* toward a final confluence with other local cyberspaces in the emerging global web of interconnected computer networks. Virtual reality refers to the patterns of ongoing events in time and space that are perceived by our senses through visual, audible and tactile interfaces. Here is how Bart Kosko defines VR in his book *Fuzzy Thinking*:

> A VR is a computer world that tricks the senses or mind. A virtual glove might give you the feel of holding your hand in water or mud or honey. A VR cyber suit might make you feel as if you swam through water or mud or honey. VR grew out of cockpit simulators used to train pilots and may shape the home and office multimedia systems of the future. The idea of advanced VR systems as future substitutes for sex and drugs and classroom training is the stock and trade of modern science fiction or 'cyberpunk' writing. (Kosko 1993)

Virtual reality has entered modern slang. Even contemporary anthropologists and philosophers use the term *virtual realities* (with no reference at all to digital technologies) to discuss dreams, myths, hallucinations and poetic fantasies, as well as a psychic fabric of scientific hypotheses, theoretical thinking, logical and mathematical reasoning, and other imaginative functions of the human mind. The shortest path to grasping the idea of computer-based virtual realities is to play a video game of car racing or, even better, war aircraft fighting, so popular among teenage boys. However, the use of simulated reality for learning purposes goes back at least to the 1960s, when professional flight simulators were introduced to train pilots and air craft controllers. They make an exemplary case, which we now consider.

Let us assume you are a novice sitting in the cockpit of a small plane that rests on the ground. Through the windshield you see a runway and adjacent airport facilities. On a panel below is the flight instrumentation: altimeter, air speed and horizon indicators, vertical velocity gauge, compass and other navigational equipment. The engine is already warmed up; your hands and feet are on a throttle lever and rudder pedals, and you are about to begin your maiden flight. By command from the digital instructor, you push the throttle to full and see the plane start rolling down the runway. Gathering speed you raise the elevator, and the plane takes off – you are airborne! Excited, you gain height, but all of a sudden heavy clouds appear with rain and a severe thunderstorm.

The plane starts banking (horizon line is tilting), and in a panic you try to damp it by turning the ailerons, but in vain. The next moment the plane dives, goes into spin, hits the ground and explodes in a ball of fire. Luckily, except for the authentic cockpit, sensual impressions, motor responses and manipulative activity of yours, everything you have seen behind the windshield or read on instruments' dials has been computer-simulated – the runway, rolling, speed gathering, take-off, height gaining, rainy clouds, thunderstorm, banking, diving and crashing. In other words, all these events belong to the domain of virtual, not genuine reality.

Nonetheless, this was a reality you could perceive and interact with as if it was authentic and genuine. More to the point, the outcome of such interaction might be quite different had you been more knowledgeable and experienced in piloting. Now this goal is within your reach. By re-starting the simulation program, you can repeat your virtual flight over and over again. Most probably, your initial attempts will end lamentably several times in a row until you manage not only to take off but also to land the plane safely. Indeed, you must try hard to avoid previous mistakes, improving your performance in operating the controls while doing climbs, glides, turns and descents, and learning how to solve various navigational problems.

It is customary to summarize the main attributes of virtual reality in three words: *Presence*, *Interaction* and *Autonomy*. These attributes are especially relevant in using the most advanced (still rare today, but tomorrow undoubtedly more frequent) VR-based educational environment.

The first attribute of virtual reality, presence, is the belief in one's authentic, or genuine, existence in the simulation. This is more easily achieved by perceiving the VR environment not on a separate screen, but inside a data-helmet with goggle-like displays, one for each eye, with sensors reading a positioning of the user's eyeballs and head. As you move your eyes and head to the left, images are rapidly updated and you feel you are actually looking at objects on the left. You may also be equipped with a pair of data-gloves (and, someday, probably, a data-suit) coupled with viewpoint control enabling you to see your hands and body in the simulation (at least their graphic or symbolic representations, say a finger, a palm, or catching glove shaped as a cursor on the screen). Presence extends the friendly, business-as-usual feeling of the iconic interface to include the actor/player/learner. The sense of presence is also enhanced if a consistent way of interacting with the microworld's objects is used. If a squeezing glove can grasp objects, the user's belief in a real, stable world naturally increases.

The second attribute of virtual reality, interaction, is the ability to change features of the simulated world in a consistent, natural, and organic fashion. This is achieved by making the data structures of the world-model mutable in natural ways (e.g., by cutting holes, lifting things, or joining them together). Properties such as conservation of volume and shape, constancy of colour and of manipulation technique, support natural interaction. The three-dimensional physical world, which in fact is logically complex, seems simple and unambiguous to people with a lifetime of experience in navigating it.

The third attribute of virtual reality, autonomy, means that the objects presented have inherent behaviours and can be trusted to exhibit them automatically when simulated. In other words, if the virtual universe plays its part, the user's mind is freed to do the creative work of designing and constructing her or his own learning projects. The task in question may consist of altering the universe's laws and testing the results.

A situation gets more complex when a student moves from a solitary activity in a closed virtual micro-world to a networked cyberspace on a global scale. For example, there are collaborative games that involve building complex worlds with hundreds and even thousands of players. It has been found in such situations that no amount of central planning on the part of teachers suffices. *Top-down* design of virtual worlds (such as is certainly necessary in packages like the flight simulator) may be counterproductive in collective games aimed at the development of creative capacities. We believe it is better to populate a pre-fabricated environment with users, to observe their needs, to provide them with tools as required, and then to let them build the world(s) they want.

Text on a computer screen is an example of virtual reality in the broadest sense. The basic human actions in this reality comprise creating a new element (typing a character), extracting (cutting), or adding part of an object (pasting). As mentioned above, this type of environment is characterized by the term WYSIWYG. Hypertexts are created in a more sophisticated manner, using a special computer language called *HTML (Hypertext Mark-up Language)* and special editors. A modern language to describe objects of all types is called *XML*. A language to create VR 3D-objects permitting VR-actions and feedbacks is called *VRML (Virtual Reality Mark-up Language)*. Three triggering mechanisms, supported by VRML, are:

1 Proximity – execution based on viewer position.

2 Viewpoint – execute when selecting viewpoint.

3 Touch – execute on viewer clicks.

A more advanced version of the language is X3D (eXtensible 3D).

Speech synthesis and analysis

Speech synthesis and analysis, as well as handwriting recognition, were touched on in the section above on hardware. We return to these topics now in the context of man-machine communication because of the importance of these channels for school.

How does one *teach* a computer to talk? How can a computer form an oral image of a sentence of text? How can we inform a user about anomalies or routine events occurring while operating a computer (technical errors, incoming electronic mail)? These situations involve *speech synthesis*.

The simplest solution is for the software maker to pronounce and record the sound beforehand. However, it is impossible to record all conceivable texts that a computer might have to pronounce, and equally impossible to dictate all possible sentences.

However, we may record separately the minimal acoustic atoms of speech, and then try to compile sonic images of words in the same manner as we compile their written images out of letters. But if we do this literally, atom by atom, we will get something unintelligible to the listener. This is especially true in difficult languages like English and Russian. As a compromise, we may record the soundings of every word in a language (quite a big job), some of the most frequent word-blocks, pairs or groups of words often pronounced in one phrase, words that sound differently when they appear in various parts of a sentence, depending on whether these are interrogative or imperative mood, and so on. Modern computers have sufficient storage capacity for such an undertaking. There is no doubt that in the near future word-by-word synthesized speech will have attained a sufficiently high quality to be marketable as a good substitute for sentence recording.

As for *analysis* of audible speech, progress in this field requires, besides an increase in storage capacity, solving what might be called the *problem of understanding*, particularly with regard to context. A computer has to be very smart indeed to understand the subtleties of human speech.

Computers for special needs

A well-known phenomenon of living organisms, including humans, is compensation – the ability to substitute some if its functions and organs for lost ones.

Computers and ICT are involved in the process of compensation in many ways. Computers can improve human senses, or substitute one for another. They can do even more, and operate different devices such as home appliances. Even for persons with the most severe challenges, the computer is a helpful tool with which to communicate and control the environment.

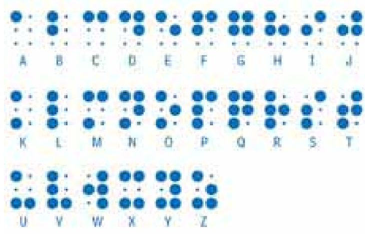
Visual disabilities can be compensated for with tactile or aural perception. Braille coding was invented long before computers, but Braille is a good example of discrete (in fact, binary) coding. It encodes any letter as a combination of dots in given positions, and so tactile reading and writing in Braille have been the form of written communication for blind people for years.

Modern ICT have improved on Braille in straightforward and important ways. There is software to translate letters, digits, punctuation marks and other symbols into Braille codes; a special printer using special paper then can print these codes and other graphical images in relief form for a blind person. It is also possible to provide online reading: on a computer extension, pins corresponding to Braille dots pop up on a template line to form Braille letters. Alternative keyboards are also available for blind people, including ones especially designed for Braille (9-keys). They include a Braille line on which the typed text is *displayed*. Keys of ordinary keyboards can be marked with Braille dot-letters as well.

Another channel of perception for blind people is aural. Besides simple recording, computers can help to transform text into audible speech (see above, *Speech synthesis and analysis*). In the simplest case, a computer reads aloud a sequential text, word-by-word. More advanced *screen readers* exploit structures beyond linear text, including hypertext. There are structures of text in programming languages and other professional environments that screen readers can navigate a blind person through.

For the non-blind, an aural channel can be used for input as well. In fact, full communication between user and computer can be based on verbal processes. A possible consequence of this is a decline in Braille literacy among the blind population, as there has been in other skills such as knowledge of multiplication tables since the advent of the calculator.

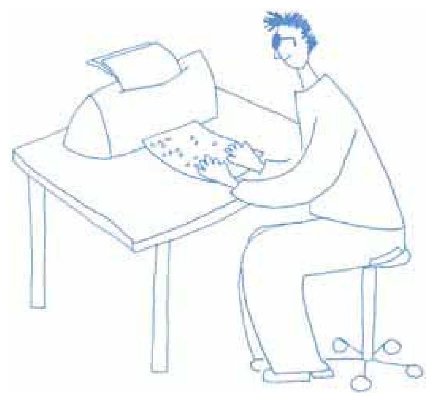
The hearing-impaired can also be considerably supported by ICT in two major ways. The first is the well-known amplification of incoming sonic signals. Unlike the old fashioned analogue hearing aid, digital devices can provide immensely wider customized choice and fine tuning of frequency equalization versus loudness levels to help compensate for an individual's aural deficiencies.



The second aid is a speech visualizer for persons with more serious hearing losses. Invented in the early 1940s and named *Visible Speech*, this device analyzed sound energy distribution of different speech formats, and displayed them as patterns of white, grey, and black patches on a monitor. The observer had the burden of guessing, interpreting, and deciding whether or not these images represented particular articulated syllables. Today, the digital automated system converts spoken words into a typed text shown on the screen. In this way, even totally deaf people can converse through the telephone or in other situations where they cannot hear a speaker's words. For blind-deaf persons, the output signals of such systems may be fed into a digital Braille display to provide the same opportunity.

In other areas, kinaesthetically (motor) impaired people can control their environment with the help of a computer and additional hardware. Text entry can be a major method of general communication for children (and adults) who have various types of problems including severe physical disabilities. Children with cerebral palsy, for example, are able to communicate more easily by using bigger trackballs. There is a whole spectrum of new and emerging input devices, including some controlled by human breath only. At the same time, human adaptation can be high. For example, some people can type quite effectively on a standard keyboard with only one hand.

To quote Nicholas Negroponte, chief of MediaLab at The Massachusetts Institute of Technology: "We may be a society with far fewer learning-disabled children and far more teaching-disabled environments than currently perceived. The computer changes this by making us more able to reach children with different learning and cognitive styles." (Negroponte 1995)



Software tools

Software, the name given to the coded instructions that tell computers what to do, comes in many different forms. Here we focus on software tools that are useful for schools.

Operating systems

The software foundation of a computer system is called its operating system (OS). It is the environment with and through which other software communicates. OS with Graphical User Interface was developed by Apple and used in Macintosh computers. The most popular operating systems today are versions of the Windows system developed by Microsoft. In the 1980s, an operating system for larger computers called UNIX was created. A version of UNIX that is popular and available for no cost today, even for less powerful personal computers, is Linux.

Personal productivity tools

The most popular application of computers today is text writing and editing, which extends to producing hypertexts and presenting Internet pages, spreadsheets, and sending and receiving emails. These tools are often called *office applications* because they are widely used and effective in offices. The dominant product integrating various office applications is Microsoft Office: a simpler but free competitor to it is called Openoffice.org.

Work with information objects assumes the ability to find any object you need. This search in a collection of objects can be based on looking for objects with specific attributes. Thus, you can look for a book with a specific author, title, or publisher. A software system that supports these kinds of activities is a *database*. One can use a database to:

- search for a particular object;
- add a new object (new entry);
- change the system of fields (for example, delete the field "publisher" and add the field "most relevant school subject"), and format of screen presentation and print-out; and
- construct a new database that makes connections with existing ones and transfer information between them.

Professional tools

In most fields of human endeavour, specific applications have been developed with specific software tools. These collections of tools are called *virtual workshops*. In fact, you can call a collection of these instruments an editor of virtual reality. They can also be referred to as *automated instruments*, or *electronic assistants* of a human editor. Thus, in certain professional fields, we have specialized mathematical text editors, sound editors, database editors, and so on.

CAD-systems, noted above, are used in different areas of design, including machine construction (for example, automotive and aircraft production), architectural design, book design, and microchip design. Naturally, specialized hardware can be required for CAD such as a more powerful CPU, monitors with higher resolution, graphical tablets, and plotters. Geo-Information Systems, also noted above, are specific tools for the design of maps and plans.

A special kind of design activity is the design of processes. Among these are:

- computer-aided manufacturing (CAM), usually based on CAD design;
- design of human activity in project planning and implementation; and
- software design (also known as computer programming), one of the most sophisticated areas of human activity today.

Numerical data processing and visualization

Under *Hardware* above, we discuss data collected by peripheral sensors such as the parameters of a physical system, biological experiment, or chemical manufacturing. Other data collected might be the results of polls and elections, which can be input manually or by using a scanner for written documents, or directly, as in the case of voting, through a computer terminal, or counting people with a photo-sensor. All these kinds of data can be organized in tables or databases, and then processed to make them *smoother*, to find, for example, median values.

Simulation

If we have a mathematical description (that is, a mathematical model) of a real-life system or process, we can simulate it with a computer. *Simulations* can be time-consuming: it might take a week, for example, to develop a really good simulation of the next day's weather. In some cases, however, we can shorten the process of simulation by using more sophisticated mathematical methods and algorithms.. A system for simulating complex systems behaviour based on differential equations and graphical diagrams is called *system dynamics* and can be implemented with the help of a software environment (virtual lab) called *Stella*.

In many cases, we may have a small piece of text (for example, the name of an information object) associated with two other pieces of text. It happens that the first and the second elements of the pair are taken from given lists, and are usually presented as a table or spreadsheet like the following:

	John	Xenia	Zulfia	Tang
Geography	A	A	B	B
Mathematics	C	A	A	A

Here we have school subjects as one list, students' names as a second list, and marks associated with them as table entries.

The situation becomes more interesting when you introduce dependences between the cells of a table. For example, you can require that the number in a cell should be the sum of numbers of two other given cells, or even the total sum of a full column. This leads to what are called *electronic* (or, better, dynamic) *spreadsheets* – a tool of visualization and simulation used by bookkeepers, economists, and others.

Control

Control is one of the most important real-life applications of ICT. Some of the processes of control are invisible, automatic, and do not assume ongoing human involvement. Others are interactive and assume the permanent participation of a human being in the system. In both cases, visualization is important.

Information sources and hypermedia

As we have seen, a great deal of information can be stored in a computer. A server, for example, with the capacity of a terabyte and costing a few thousand dollars can store the text of a million books, or about one thousand hours of video. Practically all the texts ever written could be stored in computers in one modest size building. Before long, one will be able to do the same with all art galleries, photo collections, and scanned archives of important documents, major speeches, music, and popular or artistically created movies. Nor is it necessary to have all this information in one place. The sources of information can be distributed all over the world and accessible via the Internet.

Major efforts in these directions are being made in the form of electronic libraries, digital archives, libraries, and museums, and individual attempts. Some of these depositories are proprietary and closed for outsiders or require a subscription fee; but many are free to enter, open for the public, and can be used freely for educational purposes.

In this context, two major problems arise: the *quality of information* and the *accessibility of information*. Neither problem is new. The first problem exists in the form of some tabloid newspapers or amateur writers. To some extent, control over quality has previously been based on moral and legal boundaries, but even more on economical and technological mechanisms. Distributing information widely was expensive: it pays generally, for it to be accurate.

The second problem is clearly seen in lost scientific and technological inventions, forgotten addresses and telephone numbers, and lost birth records. To deal with this problem, people invented libraries and archives, sophisticated forms of indexation and catalogues, review journals, citation indices, telephone directories, and all types of reference books, with their associated footnotes and references.

With the dawn of the Internet Age, these problems became more severe. The Internet is full of poor information and hard-to-access or wasted information. To find needed information, you can spend hours and still not find what you want. For this reason, some say the Internet is useless, even destructive and dangerous. In overcoming these difficulties, the world ICT community has invented many mechanisms.

Hyperlinks. The encyclopedia mechanism of reference has been extended enormously. A major opportunity provided by modern ICT is the ability to gather in a single computer information contained in millions of volumes contained in other computers. By using the mouse to click on a word on the computer screen, you can immediately *call up* (possibly, in a different window) a piece of information referred to by the author of the initial text who provided the link or reference. Catalogues and reference libraries of Internet resources have been developed and placed on the Internet by institutions and individuals.

Descriptions. Books and museum collections are searchable because items there have been described and the descriptions are stored in catalogues. ICT are ideal for making catalogues but descriptions need to be added. In the past few years, major attempts have been made in this direction by establishing standards of so-called metadata.

Standards. Another dimension is standards for storing data like texts and images. There was a time when you bought a new computer and a new text editor only to find that you could not read your old files. Therefore, a strong trend is to have a system of standards that are free, open, written in understandable form, and which describe how data are stored and displayed on screen.

Reusability. Many information objects are present as parts of other objects. An immediate example is a painting in a museum collection. For obvious reasons, especially in education, we would like the opportunity to access such an individual object independently. Technically it is easy, but serious organizational and copyright problems await solution.

Search engines. Major attempts are being made to keep track of all Internet information resources. This tracking can be based on an analysis of word content. Thus, you can ask a search engine to show all references to a word, or word-phrase, over the entire Internet. More sophisticated searches can be done using more complex inquiries, for instance, containing a certain combination of words, together with a particular word, but perhaps not containing some other word.

Portals. Search engines are approximate search methods, and they do not evaluate the quality of any information found. Another approach, combined with the search engine approach, consists of evaluating and describing Internet resources by particular organizations or professional associations to ensure quality of the resources as well as quality of the search, and to gather all this information in a single location, called a *portal*.

Safety systems. The mechanisms noted above do not limit access to the Internet by any computer. At the same time, there is increasing concern among parents and teachers over the dangerous influence of the Internet on the younger generation. Pornography, hate, violence, and narcotics are often targeted specifically at young people. Concerned citizens are therefore seeking to form a barrier against this influence – an Internet safety infrastructure. Parents or a school can subscribe to a safety service, and all access to the Internet will go through this infrastructure, which does not permit the user to go to proscribed websites.

Health problems associated with computers

Today, the computer is the major component of the working environment for millions of people. While working with computers can be more or less effective, it can also be damaging to one's health. The major human organs involved here are eyes and hands. Problems with eyes are caused by concentration on screen images, which are aggravated by unclear or flickering images, by glare, and from bright reflections on the screen. The problem with hand muscles is described as *Repetitive Strain Injuries* (RSI). In these cases, proper posture, exercises, and relaxation during work are helpful. For students, these considerations are even more important.

Other negative factors are excessive heat and noise. As previously noted, modern computers need increasingly more processor power for software applications. Fans installed alongside the CPU dissipate the resulting heat, but these produce noise. Another source of noise is the disc drive. High temperature can also cause emission of gases from different components of computers like plastic. There is debate about possible health problems associated with electromagnetic radiation of different frequencies emitted by computer monitors. While there is no evidence of damage caused by the electro-magnetic fields of modern monitors, nevertheless, caution is advisable because students are increasingly using computers in schools.

Repetitive strain injuries are not new. Prior to office machines, accounting clerks used to suffer severe cramp in their hands, which often led to permanent disfigurement. Pianists and other musicians suffer similar ailments from hours of practising, and sometimes promising students are so afflicted that their professional careers are disrupted. Similarly, students with an aptitude for computers may never get to reach their potential because of hours of damaging keyboarding. Video games are doing their share of damage. It is important that potential sufferers are aware that the prevention of RSI may simply require finding a comfortable and efficient posture, and maintaining a balance of movements while working.

Children are generally enthusiastic and become easily infatuated with ICT. They often keep performing an enjoyable task with great concentration until near exhaustion (e.g. making and playing their own animated cartoons for hours with few, if any, breaks). Prolonged activity without regular breaks can cause eye focusing problems (accommodation) and eye irritation.

When a student's focusing system is locked in to a particular target and viewing distance, the eyes may be unable to focus smoothly and easily on a particular object, even long after the original work is completed.

Eye irritation may occur because of poor tear flow over the eye due to reduced blinking. Blinking is often inhibited by concentration and staring at a computer screen. Desktop monitors are usually located higher in the field of view than paperwork, resulting in the upper eyelids being retracted to a greater extent. Therefore, the eye tends to experience more than the normal amount of tear evaporation, causing dryness and irritation.

Younger students are not the same size as adults. Most computer workstations are arranged for adult use and, since children are smaller, computers do not fit them well. Therefore, students using a computer on a typical office desk must often crane their necks upward further than an adult. Because the most efficient viewing angle is slightly downward about 15 degrees, problems using the eyes together can occur. In addition, students may have difficulty reaching the keyboard or placing their feet on the floor, causing arm, neck, or back discomfort.

Students viewing a computer screen with a large amount of glare often do not think about changing the computer arrangement or the surroundings to achieve more comfortable viewing, and this can result in excessive eye-strain.

Inadequate lighting can lead to visual headaches that often occur toward the front of the head, and toward the middle or end of the day. Other symptoms – eyestrain, tired eyes, double vision, and red or dry eyes – are more general. The lighting level for the proper use of a computer is about half as bright as that normally found in a classroom. Increased light levels can contribute to excessive glare and problems associated with adjusting the eyes to different levels of light.

Here are some recommendations for parents and teachers:

- Have students' vision checked to ensure they can see clearly and comfortably, and to detect any hidden conditions that may contribute to eyestrain.
- Limit the amount of time that students can continuously use computers. A 10-minute break every hour will minimize the development of focusing problems and eye irritation caused by improper blinking. Also consider having shorter, more frequent breaks.
- Check the height and arrangement of monitors. A student's size should determine how the monitor and keyboard are positioned. In many situations, the computer monitor will be too high in the student's field of view, the chair too low, or the desk too high. A good solution to many of these problems is an adjustable chair that can be raised for student

comfort, since it is usually difficult to lower the computer monitor. A footstool may be necessary to support the feet. Monitors should be placed as low as possible in front of students, and notebook computers are preferable to the desktop type.

- Check the lighting for glare on the computer screen. Windows or other light sources should not be directly visible when sitting in front of monitors. When this occurs, the desk or computer should be turned to prevent glare on the screen. Draw curtains or blinds to reduce window lighting.
- Reduce the amount of lighting in the room to match the computer screen. A smaller light can be substituted for a bright overhead light, or a dimmer-switch can be installed to give flexible control of room lighting. In other cases, a three-way bulb can be turned to its lowest setting.

Different safety and ergonomic requirements for interacting with computers and other equipment like printers have been developed in different countries. One internationally respected set of requirements has been developed by TCO, the Swedish labour association (see TCO 2004).

MAJOR TRENDS IN ICT

In the final section of this chapter, we look at major trends in ICT that might determine one's choice of computer, and what is likely to lie ahead in ICT.

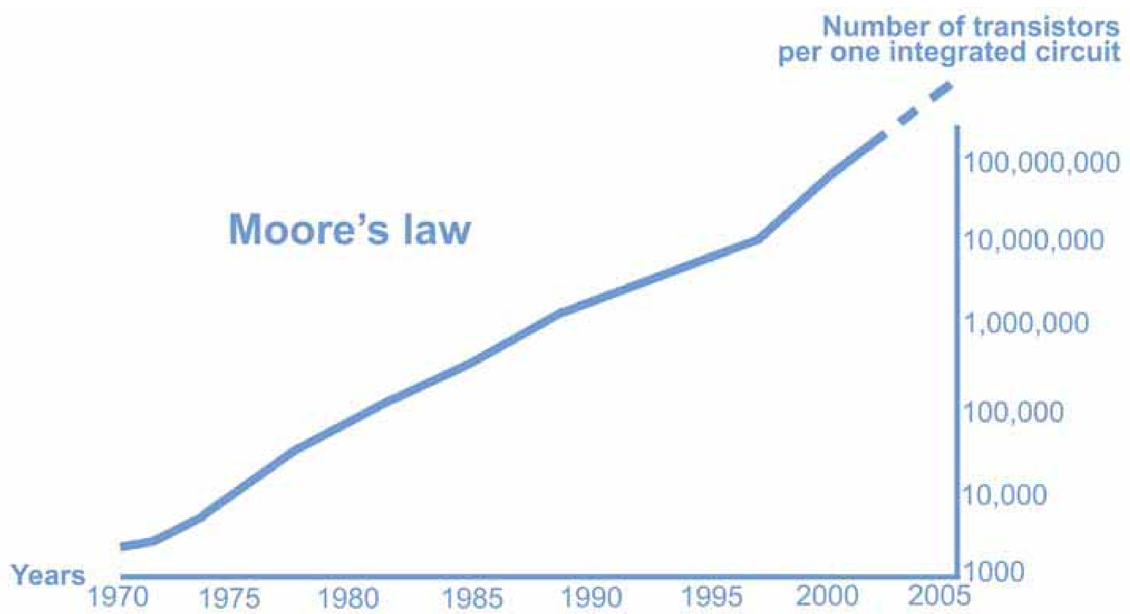
What kind of computers do we need?

Sometimes we hear from decision-makers in the field that young students need less powerful computers, and that when we want to teach programming to high school students, we need powerful ones. In fact, we believe the opposite is true. Young students need big, bright, intuitive, interactive computers.

It is more important to have modern and advanced computers in primary schools than at other levels of education because they can help provide students with opportunities to create and display according to their rich inner world, enabling them to express themselves more adequately, and opening up more opportunities for learning. Friendly interfaces, high quality graphics, and sound can dramatically extend the range of ICT applications in primary school. To achieve this, all the resources of present and future personal computers are needed. Otherwise, we risk missing that sensitive period in a student's growth when both body and mind are receptive to the acquisition of perceptual traits and symbol-manipulating skills that are essential for further intellectual and creative development. This view cannot be overstated. Unfortunately, many policy-makers in education remain unaware of these facts and are still recommending obsolete computers for kindergartens.

What changes lie ahead?

One impressive but, of course, overly simplified way to describe and predict developments in technology was formulated by Gordon Moore in 1965 in an article for the magazine, *Electronics*, on the future development of the semiconductor industry. Moore described an exponential curve of quantitative changes of computer power measured in terms of the density of microelectronic components in one integrated circuit of CPU or memory. For the last few decades we have seen this parameter double about every 18 months in line with his predictions. This exponent affects growth in computer speed and memory size. Recently, Moore (1997) announced an update to his law, but whether growth will slow remains to be seen.



What has been happening to computer cost over this time? The answer is not quite so optimistic. New technology is generally expensive; the price of a new computer model stays high for several months, then falls for a couple of years and begins to stabilize after major consumers and producers have moved to newer technology Before ending the line, liquidation prices can appear. Then old models are replaced by new ones of almost the same (inflation-adjusted or not adjusted) price, as the previous model was two years earlier, after it had fallen from its peak. In absolute figures and not taking inflation into account, we can say that the prices of the most popular personal computers are 4-6 times lower today than they were 20 years ago.

The price of ICT is determined to a great extent by the size of the market. If a tool is in demand and easy to use, the price falls. The prices of the most popular computers are slowly going down. The specialized tools of ICT will eventually be as affordable as home appliances such as TVs or stereo systems. There are good reasons to buy recently stabilized equipment. However, it is short-sighted to buy obsolete computers for schools. Accepting donations of used computers can initially be exciting; it can also lead to complete disillusionment in the technology. Even more than in other cases, we need schools to invest their additional resources in good technology, so that teachers' time can be spent on teaching and not with time-wasting obsolete equipment.

The increasing power of computers has allowed qualitative changes in human work with computers. The first computers using Graphical User Interface were a thousand times less powerful than computers of today in memory size and processor speed. We now consider the major dimensions of changes in ICT.

Consumer society and ICT

Investment in the development of more powerful computers is demand-driven. How is the demand generated? Of course, people are always interested in storing more information, and faster retrieval. At the same time, software companies are releasing new versions of their popular software that use the full power of the latest processors from hardware manufacturers. Software producers then help drive demand.

One of the results for this escalation is that powerful computers running memory-hungry applications are at the limits of their power. An unexpected consequence is that most computers have become noisier: more powerful processors emanate more heat, and to dissipate this heat more powerful and noisier fans are needed.

Ease and comfort of use

People without extensive training are frequent users of computers today. They have some skills in the special applications for their work and a vague general understanding of how a computer works. One reason for this development is the user-friendliness of computers, which means they allow you to do simple things simply. The easy-to-use Graphical User Interface (GUI), for example, permits users to rely on their intuition to operate in three-dimensional space. Like other interfaces, GUI allows mistakes (for example, in text-writing) to be easily rectified.

These improvements have allowed computers to be used by professionals from different fields. The next step is to bring some ICT to non-professionals. Today's computers are still more difficult to operate than a TV or microwave; and desktop computers are still not comfortable enough to be part of everyday life because of the space they occupy, together with heat and noise. Notebook computers do not really approach the easy use of a book. Think about how much easier it is to open a book (seconds, as opposed to minutes for a notebook computer). New options are expected.

Nevertheless, searching for information on the Internet utilizing the screen of a home TV is now possible, simple and cheap. The growing information culture and new literacy is likely to bring simpler modes of operating widespread ICT appliances, greater clarity of user manuals, and better understanding of these by lay people.

Further visualization

Visualization has been called the *second computer revolution*. The number of pixels on a computer screen and the speed with which an image changes, as discussed above, determine the quality of the computer image. Recently (on the computer technology time-scale), computers have become capable of TV/video applications. We can now store hundred of hours of TV-quality video, show it as *seen on TV*, or without advertising, and edit it as needed in a way similar to text-editing. Of course, image quality depends also on having high quality peripheral devices: for output, computer monitors and projectors, and, for input, cameras and scanners. Here, too, we can see how computer power drives demand.

Quality of sound

Improvement in quality of sound follows a similar path as quality of visual images. On the one hand, sound requires less memory and computational power to work with. On the other hand, manufacturers and consumers usually underestimate the value of computer sound. Sound quality is important from psychological, emotional, and ergonomic points of view. We expect higher standards of computational power to improve sound quality and to herald more applications of sound, as well as in speech synthesis and speech recognition, language and early learning.

Human movement and other types of communication

Currently, a person interacts with a computer mainly in two-dimensions. The keyboard and the mouse are operated as discrete objects. The computer screen is a *desktop*. Is it possible to move to another dimension, one that allows objects to be grasped, touched, moved, and smelled? Numerous research projects are underway, some of which promise to become part of mainstream reality in the next decade. Intensive research is going on, for example, in the fields of kinaesthetic input and output. A computer will *feel* human movements visually or via special sensors. It will also provide feedback through gloves with motors in them. Smell input (and output) is also in the experimental stage.

Computer reaction to movements – for example, changing visual images in response to a head turn or other non-verbal cues – can be achieved with the use of trackers mounted on head or fingers, or seeing human movements. A haptic device involves physical contact between the computer and the user, through technology such as a joystick or data gloves that sense the body's movements. With a haptic device, the user can feed information to the computer and receive information in the form of sensations on parts of the body. For example, in a virtual reality environment, a user could pick up a virtual tennis ball using a data glove. The computer would sense the movement and move the virtual ball on the display. At the same time, the user feels the tennis ball in his hand through tactile sensations that the computer sends through the data glove, mimicking the feel of the tennis ball in the user's hand.

That type of interaction can be implemented with an *exoskeleton* – a system of artificial bones and muscles (electric motor-based) tied to the human body to imitate reaction of the environment. In particular, force feedback (FFB) simulates weight or resistance in a virtual world. Force feedback requires a device that produces pressure on the body equivalent or scaled to that of a real object. It allows a person in cyberspace to feel the weight of virtual objects, or the resistance to motion that they create. Tactile feedback (TFB) produces sensations on the skin, typically in response to contact or other actions in a virtual world. Tactile feedback can be used to produce a symbol, as in Braille, or simply a sensation that indicates some condition such as heat. Touch and hold are not the only physical relations in the real and virtual worlds. The proximity of an object can be manifested by a sound, for example. Sound can also represent execution of a procedure like opening a door or giving a greeting.

To summarize, we see among existing and emerging extensions of the usual computer interfaces the following:

- Larger screens, including touch-screens.
- Stereoscopic images (different for different eyes).
- More use of trackers.
- More proximity.
- More sound feedback including proximity.
- Computer-generated odour.
- More accurate and sophisticated force feedback.
- Tactile feedback, specifically aspects of touch not covered by force feedback.
- Accurate simulation of the behaviours and other characteristics of soft tissues.
- Integration of data from several sources.
- Integration of the real world with virtual worlds or switching between real and virtual worlds.
- Video and audio input via head-mounted devices simulating human perception.

Computers to go

The real limitations of computer size, weight and portability do not follow from its computational or memory power, but from the ability of humans to receive information (via video-monitor) and to send information (via keyboard). Therefore, the following general options exist:

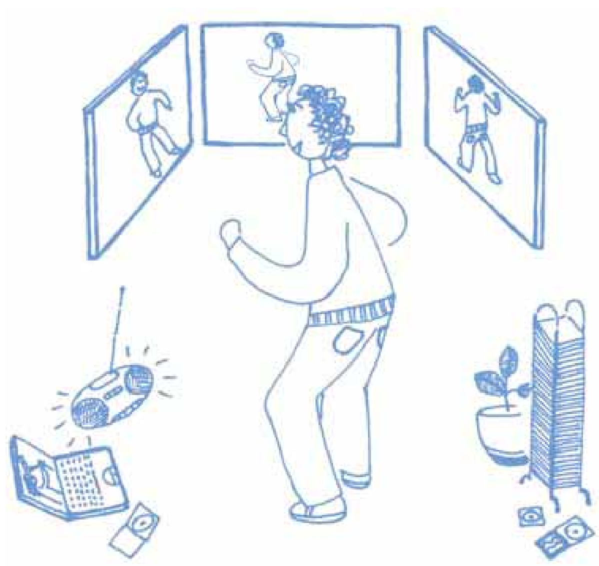
Notebook computers are complete computers with full functionality and with all major devices of the desktop computer. A popular current version does not contain any drive for removable discs (floppy, CD or DVD), but has USB ports to which you can plug in a flash card or external drive. Notebooks can communicate with all peripheral devices via RF and IR channels, and with the outside world via radio-channels as well.

To make it even smaller and cheaper, there are also **sub-notebooks** that have a less convenient keyboard, smaller and weaker display, and less functionality, in particular, usually having a less powerful OS than desktop and notebook computers.

For greater savings, you can get **smart keyboards** with a very simple (for example, 8 lines of text) display, with the major function to store text input. The price can be 3-4 times less than the price of a regular computer, and so this is a popular option for schools.

Palm computers or palms have the functionality of sub-notebooks, but are even smaller with just a screen of palm-size. The screen is used also as an input device for handwriting, pointing and moving objects. Palms are really good for taking notes on the move, and for collecting data from different sources (like measurements from sensors).

Wearable computers



The changes discussed immediately above lead next to the concept of wearable *computers*. The key devices of wearable computers are *glasses* through which computer images are displayed (in particular, these can be images of real reality). A pair of stereo glasses can be fitted with a pair of stereo speakers, and a microphone in a VR-helmet.

A further idea is *to wear* a computer that has no input-output devices in it, and is connected to the world through wireless channels only. Such a computer might receive your email, for example, but to read it you need to come to a screen with a wireless interface compatible with the computer.

A wearable computer would *recognize* context – that is, it would *know* not only "what time is it now", but also "where you are" and "what is happening around you" and "how you feel".

Local information space

A VR-helmet is a very *local* presentation of the information space to a human. There are other means for providing comfortable access to information and instruments to work with at home, at work and study places. These include:

- Screens and speakers for output (including touch screens, for output and input).
- Wireless keyboards, mice, hand-held scanners, and speech recognition devices for input.
- Common information space for all points of access organized for sharing by many users.

For example, in a school-and-home integrated network, students could come to any computer with their keyboards, or even mobile phones, and enter their own information space incorporated into the school information space and global information space.

The human element

Physically, access to information is limited by a computer's communication speed, which is limited by bandwidth, and this, in turn, is limited by frequency range. However, the human factor is more critical here. Everybody seems to agree that Internet surfing can be even more harmful for children than TV-viewing. Sophisticated search engines and agents can help but most of the work to make information available and to ensure its quality must come from humans. Therefore, the Internet community and infrastructure of support of many other people are needed.

Merging of mass media and the Internet

As previously indicated, computers are now integrated with television. Cellular telephones give you a keyboard, a TV-screen, and an Internet connection. Increasingly, content, media, and devices are integrated in a digital format.

Computers also serve for information searching, storing, and processing (for example, to find a TV transmission via an Internet TV-portal, or to cut out commercials and store a show along with adequate text description).

More models of reality

Even an autonomous, non-Internet-connected computer is a powerful device for constructing your own information objects – indeed your own models of reality. Constructing static objects, books, and graphical art can require considerable computational power. Even more power is needed for computer simulation and visualization of the results of the simulation. Progress in this direction is based on increasing computational power and, even more, on developing more sophisticated tools that are comfortable for human use.

More understanding from computers

From the beginning of the computer era, the idea existed to delegate to the computer the most sophisticated functions of the human brain. Progress in this area has been slower than expected. Eventually, however, some of the hoped-for developments have occurred, for instance:

- Computers now play chess better than humans.
- Computers recognize oral speech and handwritten words.
- Computers recognize objects in environments and act accordingly.

From these activities and achievements, we see now that the critical issue in further progress is building up more computer models of physical and psychical reality (that is, more understanding of the world).

Economy of ICT

Unlike matter or energy, an information object can be consumed many times with no additional cost for its reconstruction or refuelling.

Digitization prices have dropped, so that it is becoming affordable for libraries to make their unique collections digitally available. Huge libraries can be stored on a single desktop server. CDs and DVDs have become easier to copy in the technical sense. It is not hard for pirates to break copyrights. More and more music is available on the Internet, and music albums of a favourite composer can be stored on one DVD. Information tends to be free.

From this perspective, there is a growing interest in the UNIX operating system. Originally developed as an advanced, heavy-weight, and hardware-demanding operational environment, but more robust, reliable and safer than Windows or Mac OS, UNIX, and especially its modern lighter version Linux, can run on smaller computers than today's versions of Windows. And Linux is free of charge, as are many applications developed for it. Other applications, like OS Lindows and applications for it are much less expensive than most commercial software.

In fact, there is a lot of free information on the Internet. Several countries have launched free electronic archives, and digitized their cultural heritage.

The idea of open and free information space is at once popular but also disturbing, not only among educators, but among software developers as well. Many software products in schools are open and allow:

- teachers and students to use data and images for their personal use;
- students to create experiments in virtual labs, and teachers to create tests; and
- students to store their work for a period of study in a unified information space open to other students and teachers, parents and other schools.

The major question is how will the creators of original information work be paid for their work. A possible answer is that information will be free, but that human service provided on demand will be compensated adequately. Questions of further development of free information resources are under consideration currently by an important international association called The World Wide Web Consortium (W3C).