3

SCHOOLS IN TRANSITION

TEACHERS AND LEARNERS

Before focusing on ICT in classrooms, which we do in Chapter 4, this chapter provides some background in pedagogy, and examines what is involved in teaching and learning, as well as the institutions – schools – that we have developed for teaching and learning.

Educational events

An educational event occurs between someone who is willing to educate, namely the teacher, and another, willing to be educated, the learner. A synergy of wills is a prerequisite. Otherwise, there is no place for proper education, and we should talk about conditioning, drilling, training, moulding, pressing, or whatever else might happen between those officially labelled as *Teacher* and *Student*.

The teacher is always in search of a learner, and vice versa. When there is no learner in sight, teachers will try to awake, or invoke the will to learn in anyone they happen to meet. The teacher does this by challenging the other person's curiosity, ambition, inquisitiveness, or just playfulness with any means at hand. Anything that works is good for this purpose.

A learner is also always in search of a teacher. Where there is no teacher available, learners will recruit anyone they meet as a possible teacher. If there is no one at all, they will figure out a kind of virtual substitute teacher inside their own soul.

We discern three facets of any educational event: encounter, communication and interaction.

1 Encounters are face-to-face meetings; situations when you find yourself faced by other individuals and feel prompted to relate somehow to their presence.

2 Communication is an exchange of messages, sent and received by at least two people, expressing their feelings, thoughts and intentions to each other in the hope for reciprocity.

3 Interactions are processes where two, or more *actors* (in our case – teacher and learner) influence and affect each other's actions and behaviour while striving to reach their goals, doing some common work, or performing a joint task.

Any interaction, by definition, generates information. Not all information generated by an interaction needs to be communicated; some parts of this information may be intentionally concealed. One actor may purposely search for, uncover (at times compel), and collect the information that another actor tries to conceal.

At times it is difficult to draw a strict line between communication and interaction. For example, if during language classes (especially on rhetoric), a teacher uses verbal means to enact modes of argumentation for students, communication and interaction become one and the same. A number of authors, analyzing patterns of communication in European cultural (especially educational) traditions, have pointed out such recurrent themes as surveillance, interrogation, and the threat of punishment.

Basic activities in learning

Let us recollect some well-known facts about human information activities and other actions in the process of learning that will later be transferred into ICT contexts.

Communicating by different ways and means

For centuries, communication between human beings has been carried out in oral and written form. Oral communication goes through the aural channel of information, more often than not supported by the visual channel (a speaker's movements and everything else that constitutes theatrical aspects of communication).

Oral communication used to be immediate until recent centuries when it became possible to have it recorded. It was an interesting moment in human history, when the recording of dynamic images of communication (as well as images of the world) was invented and developed, before the recording of dynamic sound was possible. This was the era of the Great Mute (as they used to call the cinematograph until it was coupled with recorded sound), where moving pictures on the screen were accompanied by subtitles (and live music) only.

Communication can go in one direction as in radio and TV broadcasting, or in two directions as in oral discussions or telephone conversation.

Written communication goes through a visual channel, where text is supported by pictorial illustrations.

All these models and modes are presented in learning and teaching, and all have been, and are being, radically changed by ICT.

Object making

Learning can involve also doing something in the physical world, particularly, making objects. This includes making messages, which, in this respect, intersects with the communication process, though the accent in the doing is made on constructing the message, not delivering it. Therefore, cases of doing in learning are represented by constructing:

- an information object (an actual or potential message),
- an information process (composing and editing),
- a mental, inner object (reasoning and imagining), and
- a material object or process.

These activities, while being in many aspects interrelated, can be efficiently supported by different uses of ICT.

Observation, reflection, imitation

Observation is another process involved in learning. The learner is an active participant in the game here. A further important element in the formation of a thinking human being is reflection – the process and the ability to observe yourself and your activity *from the outside*. An ancient and powerful tool for reflection is a mirror. Observing another human in order to copy, imitate, and do the same, is another important model of learning. The modern type of mirror that keeps track of disappearing images is a video-recorder.

Information searches and questioning

Searching for information was not a popular activity in traditional schooling but has become more and more important in modern life. Previously, if any searching was done, it was primarily in a person's memory. People were considered intelligent, knowledgeable, and wise if they could *output* quickly the needed information from memory. Even then, books (of wisdom) were occasionally used to answer a question, but the books were not considered as an everyday source of information with the exception, perhaps, of medical doctors and lawyers. Today the search and retrieval of needed information is becoming a core activity in work and learning. Asking an expert is a special case of information search.

The faculty to question was recognized long ago as a mark of the genuine philosopher and scientist; but it was also reflected in ironic sayings like "One fool can ask so many questions that a thousand wise men will never answer". As with information searches, questioning is becoming more and more important in the information age.

Receiving aural and visual information in studying a school subject is a prerequisite, but it is just the first step to assimilating its content. True learning occurs only in an intensive conversation between teacher and student, as well as between students, as all good pedagogues since the days of Socrates have known. What a pity that this principle was forgotten, or neglected by those teachers in many 20th century-era schools who thought they were there to teach, not to converse.

CONTRADICTIONS OF SCHOOLING

Contemporary education is replete with contradictory demands. Here we touch on some of these.

Creativity versus discipline

Perhaps the most tormenting question of contemporary education is how to reconcile two contradictory demands:

1. fostering inquisitive and creative minds eager to explore the unknown and solve unprecedented problems; and
2. training the same creative minds to become skilful, adroit and highly disciplined performers of particular, subject-specific, manual and mental tasks.

To a large extent, the lamentable rift between verbal and practical, hands-on learning, so deeply rooted in the established system of schooling, aggravates this contradiction. The contradiction is compounded when you consider the further problem of motivation, which has been moved to the forefront by all modern pedagogical theories.

Compulsory versus voluntary

Can you force a small child to play? Obviously, not. Children start to play only when they feel like playing. Equally, no teacher can force a student to learn actively and wholeheartedly unless they have a deliberate desire to do so.

Of course, we can, and often *do*, teach appointed subject(s) to students and make them learn quite successfully, judging by standard achievement tests, without any strong need and desire on their part. So, what is wrong with that?

The trouble with *compulsory* (that is, passive) learning is that while students appropriate a given piece of curricular content quite firmly, they all too often remain incapable of *applying* it to anything else besides right answers and getting high examination scores. As it happens, a student often cannot relate a newly acquired fragment of knowledge to other pieces learned previously, especially in other subject areas. Unable to connect recent acquisitions to what is already known, and to perceive the outcome as coherent whole, they can hardly be expected to transfer a powerful mathematical concept into a field of science in order to grasp the laws of physics and chemistry, or use the latter for better understanding of a living cell. It goes without saying that these disjointed chunks are even harder for students to apply to real-life issues outside school.

Schooling can bring forth truly substantial results only when coupled with inner motivation and self-propelled learning – in other words, when particular skill development is driven either by genuine curiosity, or by some pragmatic consideration as, for example, when seeking to find a clue to some intriguing riddle, or to solve a problem one has stumbled upon in a game.

We are back at our starting point. Is it possible for teachers not to compel and coerce, but to provoke, entice, or tempt students to embark on truly *active*, all-absorbing and penetrative learning? And, if so, then how?

There is strong reason to believe that ICT can help bridge the yawning gaps just described. First, however, it is worth recollecting that students generally *want* to comprehend a particular subject or master a methodological cornerstone of so-called classical schooling and, second, summarize the criticisms of this schooling, and review proposed alternatives.

Classical hierarchy of learning and personal responsibility

In medieval times, knowledge was a set of divine commandments transmitted from a teacher to a student, who was obliged to take them reverently and obediently. Later, Nature and its laws displaced the Deity, and the teacher's duty was to provide students with the knowledge of those natural laws, discovered by scientists, that would lead the human race further along the path of progress.

Three fundamental educational assumptions that date back to Socrates and later Descartes have until recently been taken as unquestionable:

1. Simple skills requiring little understanding are the easiest to learn and therefore easiest to teach the youngest or the mentally less capable.
2. There is a hierarchy of skills from simple to complex, and a hierarchy of performance from that requiring little understanding to that requiring abstract knowledge. To move up this ladder, the preceding rung must be mastered. In other words, Lesson One must be mastered before the student can successfully move on to Lesson Two.

3 There is a progression towards maturity that must be followed: the very young or the retarded cannot learn via abstract understandings and therefore must be taught by the route of simple skills and bits of information, which they eventually combine into large units.

Under this system of education, a team of workers or mental *agents* must manage learning activities, each performing a single, elementary function. This hierarchical organization is something like a tree in which the agent on each branch is exclusively responsible for the agents on the twigs that branch from it. It is easy to construct and understand such an organization because each agent has only one job to do: it needs only to *look up* for instructions from its supervisor, then *look down* to get help from its subordinates. Metaphorically speaking, these agents constitute something like a *machine* built purposefully to manufacture these particular, strictly specified products.

We do not doubt that there is room for teaching and learning certain disconnected, step-by-step accruing skills, required by many occupations, by this method.

But the great realization of the 21st century is this: no scientist, political leader or preacher knows for certain how to decide on this or that issue of global scale, nor what advice to give any of us on our daily cares, living in a world that is changing in all its facets at an ever accelerating pace.

The destiny of mankind depends, rather, on decisions made (or not made) by each conscious and responsible person. It has become crystal clear that the long-established and respected ways of teaching in schools are not good enough. We must be concerned, not with adapting to a given world out there, but with making this world different.

The educational system of the 21st century must be oriented toward creating conditions that allow school students to act and learn freely in productive collaboration with their teachers, and also with their parents and other members of their community, local and global. In this, the application of ICT appears to be a necessity, as well as a pledge of success.

OLD SCHOOL AS ORGANIZATION

In the previous two sections, we describe basic relations and activities of learning, and expose certain basic contradictions of schooling. As we see next, existing schools fail to exploit most of these relations and activities and do not contribute much to the resolution of the various contradictions. After investigating the limitations of what we call *old schools*, we outline the psychological background of possible changes that are occurring, and then proceed to the changes themselves.

Activities to sustain

It is assumed that readers are familiar with how the *mass*, *standard*, *traditional* school works today. Let us call this the *old school.* To redesign such schools with the help of ICT, we need to take a fresh look at them as though we have never seen such enterprises before. We need to consider them anew and decide what to take into the future.

School-related activities can be broadly divided into two categories – internal and external – that the school as an organization is called upon to sustain.

Internal activities are carried out within the school's scheduled hours and inside the school walls. These core, central, obligatory and strictly formalized activities – one is tempted to say almost *sacred* activities – are the school's classes or lessons, comprising teaching and learning. Activities during intermissions are *profane*, and activities after scheduled hours are a mixture of the two. There are also internal activities of administration and supervision, and teachers' meetings, which are conducted without the involvement of students. All these activities imply an exchange of information, carried out through a number of channels, some established, officially approved, and highly formalized; the others, informal, weakly delineated, not always approved, often rebuked and prohibited, and thus covert, and even kept in strict secrecy.

External learning activities, besides sports and clubs, are mainly homework. Students do their homework in an isolated, individual manner. The relation to internal activity is often through short assignment notes. Consultations with teachers, discussions with peers are occasional and irregular, as is cooperative work. External activities of school administrators are working meetings and consulting with superiors and colleagues from other schools, seminars, training sessions, and conferences.

The learned context of learning

Neither organizational aspect of schooling should be neglected in relation to the use of ICT. As Penelope Eckert puts it:

> One of the greatest errors in education is to assume that the larger social context of the school is irrelevant or even secondary to learning. ...The social structure of the school is not simply the context of learning; it is part of what is learned. What a student learns in the classroom is indeed a very small other part... What the Burnouts learn in school is how to be marginalized... High school, therefore, is not simply a bad experience for these students – it teaches them lessons that threaten to limit them for the rest of their lives. (Eckert 1989)

Writing about business organizations, rather than schools, managerial scientists often refer to *learning organizations*. Here is what one writer, Ronny Lessem, says in a paper titled *Linking artisan and scribe:*

> Since at the present rate of technological change the problems to be solved differ from one day to the next, it follows that everybody in the organization, from those who frame the policies to those who manipulate the ultimate details of technique, must be endowed to the possible extent with the *means of learning* [our italics]. (Cited in Rhodes 1991)

One must ask here whether the school can evolve and change its structure and functions in response to the new challenges. Is the present school an organization that learns, or it is just a system, a machine, functioning according to predetermined and inherently closed programs?

School as a social institution

Lewis Mumford, an outstanding historian-philosopher of technology, described the new kind of religious, socio-political, industrial and military organization, invented during the Bronze Age under the aegis of the priest-kings, as a *megamachine*. Being essentially coercive, undemocratic and hierarchical, such an organization paved the way to, and was inherited by, succeeding civilizations. Only recently was it questioned and challenged by a new vision of human progress based on other principles. (Mumford 1966)

Through this millennial old legacy, the school appears to be the social organization most resistant to change. In fact, it mostly strives to keep its basic structures and functions unchanged, including its information circuits, channels, and routes. Below, we examine typical approaches to channelling information, which, in turn, were determined by the traditional concept of so-called compulsory mass education. To make things clearer, however, we must trace the latter's origins back to three or four centuries ago.

There was no serious lack of quality as long as education remained a heavily guarded treasure or luxury, accessible only to a chosen few. Formal schooling was reserved exclusively for the high priesthood and aristocratic families, and denied to anyone outside the cloisters and castle walls.

School as an invention of industrial era

The *classical school*, as we know it today, was invented at the dawn of industrial, mass-production-of-everything era. General education was claimed as the property of the people at the verge of the 17th and 18th centuries in Europe. Just and democratic at its inception, this path led in time to quite a different state of affairs. Historians and theoreticians usually say the school was first modeled after a printing-house – as Comenius announced in his 1657 book, *A Living Printery, or An Art of How Swiftly, Yet Informatively and Lightly to Stamp the Wisdom Not On Paper, But Upon the Minds*. It was not just a coincidence that schools were associated with the most advanced information technology of the time – the printing press with movable characters. The minds of pre-schoolers were considered a plain tablet or a blank sheet of paper upon which teachers could write anything they, or some higher authority, would think appropriate. In a short while, the thinking about what was appropriate to teach children was taken away from teachers and concentrated in the hands of those in political and economic power.

No less significant technologically and educationally was Gutenberg's concept of setting up a line of type by using separate letters cast in a uniform pattern in a mould: the origin of the standardized, replaceable part of ever increasingly automated machinery. It was only logical to apply the same principles to schooling, and since the mid-19th century, this approach has prevailed in most Western countries. A system was established where children and young people could learn different subjects from different teachers who, in their turn, could rely safely on a standard, ready-made curriculum and procedures designed by other specialists.

Information routes and flows in the classical old school

At the top of the said system, we see centralized pedagogical research institutions that design the curricula, instructional methods, textbooks and other materials, which, after having a stamp of approval from ministries of education, are distributed to schools and teachers. A teacher's duty is to read and follow closely the body of these materials in order to deliver it piecemeal to students, who are expected to memorize the content one chunk after another, and checking in to see if they succeed. The basic, though rarely announced, assumption is that teachers need not add a word to what has been given from higher authorities.

A principal and a supervisor receive from the higher educational authorities an approved bundle of curriculum-and-procedure materials and distribute these different packages among the teachers of particular disciplines. Each teacher subdivides the received package in accordance with the age grouping of students, the quotas of curriculum content to be assimilated daily, and the school timetable. Teacher-to-student communication is predominantly oral. Visual aids are usually illustrations taken from books. There is little hands-on activity with physical materials and tools on workbenches. The teacher is a lecturer, not a master of a craft (menial or mental). Little communication exists between teachers of different subjects on how to collaborate in making the educational process truly involving and exiting.

What teachers and learners do during classes

Here is a brief list of what teachers and learners do in the traditional classroom of the old school:

- Teachers speak, learners listen.
- Teachers talk to learners, who listen to and supposedly perceive, understand and memorize what is said. Often, this is all that teachers do on a strictly formal, *technical-operational* plane.
- Teachers write letters, numbers, words and phrases on the chalkboard to help students hold facts in their short- and long-term memories.
- Teachers paste (clip) to the chalkboard, or hang on the wall, posters with pre-written (printed) letters, words and numbers, and then point to them with their finger or a pointer while giving explications, explanations and instructions.

- Teachers draw or use ready-made diagrams or images of certain objects or scenes related in some way to what they are saying.
- Teachers bring three-dimensional objects to illustrate lessons.
- Teachers manipulate these 3-D objects (other than to point to them or take them in their hands to show them to the class) in a transformative way, for example by using them in applied functions they are meant to illustrate. To show such manipulations and transformations of 3-D objects, teachers use workbenches.
- Teachers conduct spectacular experiments that excite students and which they remember all their lives.

In short, notwithstanding the content, the main tool and carrier of the teacher's message is the word, or, more precisely, the oral and, to a lesser degree, written speech. At the same time, we know that the additional activities are listed in ascending order of their supposed educational efficiency (and labour intensity).

In such classrooms, learners are not required or expected to:

- *do* anything besides follow a teacher's presentations and instructions expressed in oral and written words (texts) until they can assimilate and reproduce verbally the knowledge and skills required;
- *draw* in language or mathematics workbooks except perhaps for geometry, or drawing primitive diagrams for science (in most cases, learners are not taught to acquire drawing skills);
- *manipulate* or transform three-dimensional objects, other than, perhaps, paper, scissors, glue and pencils.
- *discover*, invent, design, and construct during classes anything of their own in relation to the curricular content; or
- *converse* with classmates on the content being taught.

This picture may be over-simplified, but it broadly reflects the features of the traditional school that are deeply embedded into organizational structures in many countries.

Rigid timing

In a scheduled class period, the teacher delivers (orally, in blackboard writing, and by showing pictures) the assigned chunk of information simultaneously to all students in a monologue *broadcast* type of lecture. While taking in information coming from the teacher, students are obliged to remain silent and motionless until the teacher stops the delivery and asks them if everybody has clearly understood what was said. Then those who may not have understood can raise their hands and, after being granted the right to speak, say what escaped their comprehension. Teachers repeat an explanation twice or even three times, but often there is no time to clarify all problems, and there are always one or more students who dare not express their difficulties. Common sense prompts one to think that those who are in need might seek and find some help from their nearest neighbours in the classroom. Sadly, more often than not, such a common sense approach does not happen in *classical schooling*.

As everybody knows, communication between students during classes is usually frowned upon because it threatens to disrupt the very foundation of *classical teaching* (luckily, there are many good teachers brave enough to transgress this rule).

Monologue lecturing

Information is constantly filtered downwards through the hierarchical system and no horizontal roots are stipulated. When a teacher gives a class an assignment demanding writing, calculating, or reasoning, each student is supposed to do the task individually and by themselves. No consultation with classmates is allowed, and any breaking of this rule is often punished. Consequently, nothing even remotely resembling collaboration, productive discussion and teamwork is practised; neither are the corresponding skills being developed. As a result (and this becomes evident after some testing questions made by the teacher), not all students receive the full amount of curriculum information supposedly transmitted to them during class periods.

Students do not have the channels, and nor are they encouraged, to exchange views and opinions about the curriculum. It is not surprising then that very few of them are motivated enough to discuss such things out of classes except to complain about it. Anyway, such behaviour is not anticipated or wanted in traditional curricula and procedures.

In such circumstances, one might conclude that most traditional school authorities would readily reject the idea of adopting ICT that would enable students to sustain autonomous information exchanges during classes.

Institution for teaching only

Because of society's evolving expectations of equal educational opportunity for all and the current emphasis on relevant and quality opportunity for all, the school system has developed into an increasingly complex organizational structure. This structure requires extensive and comprehensive administration and has enough problems sustaining stable and malleable conditions to put aside the problems of its transformative development. That is, to sustain the conditions that give teachers and administrators intellectual and emotional comfort, they naturally tend to see schools as exclusively teaching institutions. They have little time to think about schools as learning institutions and do not consider it a pressing priority. What are the consequences? Howard Gardner puts it this way:

> We run the risk of investing incalculable resources in institutions that do not operate very well and that may never approach the effectiveness that their supporters – and for that matter their detractors – would desire. Moreover, ...until now, we have not fully appreciated just how difficult it is for schools to succeed in their chosen (or appointed) task ...We have not been cognizant of ways in which basic inclinations of human learning turn out to be ill-matched to the agenda of the modern secular school. (Gardner 1991)

The curriculum: a sum of disparate subjects

The sum of what must be taught and learned, despite the charge to have it integrated and holistic, remains a collection of disjointed, isolated and unrelated subjects, struggling for allocated hours in the school timetable. No evident connection exists between corresponding activities or between actors *(functional agents)*; no channels through which they can communicate and talk to each other; and no space for their mutual encounter and subsequent interaction.

Quite naturally, there is little information exchange between them precisely because subject matter in the classical school curriculum is impersonal, faceless and soulless. Neither teachers nor students can feel and see in such classrooms other living, willing, and acting personalities – those bearers of creative forces that had once brought into being all these areas of knowledge, mastery and expertise. No wonder they have little motivation to explore and develop the hidden inner potential of their own.

The origins of detechnicalized learning

The mechanical-industrial syndrome is still felt in many areas of education, especially among the administrative staff. The vision of a smoothly run manufacturing plant with its driving belts and assembly lines does often eclipse the fact that school is (or at least, is said to be) a living entity, a society in miniature, a learning community of people, comprising some adults but mostly children drawn and bound together by extreme variegated needs, expectations, obligations, and responsibilities. To quote Seymour Papert who probably, more than anyone else, has helped us to understand the vast educational potential of computers:

> The institution of School, with its daily lesson plans, fixed curriculum, standardized tests ... tends constantly to reduce learning to a series of technical acts and the teacher to the role of technician. Of course, it never fully succeeds, for teachers resist the role of technician and bring warm, natural human relationships into their classrooms. But what is important for thinking about the potential for megachange is that this situation places the teacher in a state of tension between two poles: School tries to make the teacher into a technician: in most cases the sense of self resists, though in many the teacher will have internalized School's concept of teaching. Each teacher is therefore along the continuum between technician and which I dare call a true teacher.
>
> The central issue of change in education is the tension between technicalizing and not technicalizing, and here the teacher occupies the fulcrum position.
>
> Not since the printing press has there been so great a surge in the potential to boost technicalized learning. But there is also another side: Paradoxically, the same technology has the potential to detechnicalize learning. Were this to happen, I would count it as a larger change than the appearance on every desk of a computer programmed to lead the student through the paces of the same old curriculum. But it is not necessary to quibble about which change is more far-reaching. What is necessary is to recognize that the great issue in the future of education is whether technology will strengthen or undermine the technicalities of what has become the theoretical model, and to a large extent the reality. (Papert 1993)

In fact, institutionalized, compulsory education was turned into a machine (a mechanical production system), imparting its *products* with an inner program to proliferate the same pattern in all walks of life. Hence, the school became the model for the mechanization of society. Increasingly fragmented division of labour and specialization were, and still are, the key words. In fact, it was a cycle (or vicious circle) of mutual reinforcement that reached a climax in the mid-20th century.

At the beginning of the new millennium, this cycle came to a dead-end. To become alive again, we believe the school must transform itself from a machine for teaching into a *learning organization* more focused on creative experiments than on prefabricated detailed plans and checklists.

THE BASE FOR NEW PEDAGOGICAL POSSIBILITIES

Proposals for a radical reformation of traditional schooling are numerous. To explicate them all here would be a large task. However, we shall try to give instead a composite picture of the leading ideas that we deem the most promising, substantiated, and convincing. We start with basic notions, describing child personality and development, and with the question of how to measure them.

Intelligence and intelligence quotient

Dictionaries define intelligence as the power of seeing, learning, understanding and knowing. It is a mental ability. For example, we say, "He shows little intelligence" when we mean that boy is slow in understanding.

For a long time in the West, *intelligence* has been equated with the ability to think *rationally* and *objectively*, and to express one's thoughts and judgments in *scientifically based*, *quantitatively measurable*, *logically provable* propositions and assertions. Individuals were called intelligent if they were astute, shrewd, eloquent and quick in using words and numbers, especially in written form. In the Orient, by contrast, a man or woman who was well behaved and obedient to the supreme forces, respectful to the elders, deferential to traditions, or endowed with clairvoyance, was often referred to in terms that have been translated as *intelligent*.

Consequently, teaching and learning in Western schools were more concerned with transmitting and getting *detachable* and *distant* knowledge coded symbolically in oral and written speech, rather than with immediate interaction and participatory hands-on activities, experience and wisdom.

It was quite natural to establish a system of checking and testing both interim results and the quality of the end-products of this almost industrial-like manufacturing process.

At the turn of the 20th century, the French psychologists Binet and Simon were commissioned to research the possibility for *measuring intelligence*. From the start, the goal was to measure the sub-skills necessary for classroom success. Binet actually sat in a classroom, taking notes of students' answers to teachers' questions, and tried to construct rules for predicting who would fulfill the demands of the teacher best.

Sampling school children's abilities to utter correct answers in many schools across France, Binet created the first intelligence test, later developed and corroborated by other researchers. With these tests, it became possible to estimate an individual's *intelligence* by processing the data of one's performance on a deliberately heterogeneous set of items, ranging from sensory discrimination of colours to vocabulary knowledge, and to calculate a so-called Intelligence Quotient or IQ.

What a magnificent epitome of the era of mass-produced education: now you could quantify how bright and stupid everyone is!

In pre-industrial epochs, people perceived each other as much more complex entities. Someone could be clever enough with words while incompetent in numbers; shrewd in business but poor in writing; incapable in abstract reasoning but masterful in crafts or apt in sports. It was only after the development of intelligence tests and what the statistician Spearman did with them that the construct of intelligence nested so firmly in the consciousness of educators and heads of Human Resource departments.

Spearman found that all IQ tests that appeared after Binet and Simon's correlated highly with each other. He reasoned that they must have been measuring the same thing. Further, this cross-correlation could be explained by a construct he called *g*, for *general intelligence*. Some eminent critics disagreed, maintaining that human beings had multiple abilities, or factors of intelligence, but they were forced to admit that even these multiple factors had a high cross-correlation. Hence IQ tests became highly useful in the hands of busy school administrators eager to predict student scores and channel students according to their abilities. After all, that was how the administrators' own abilities would be measured and rewarded (or punished).

Eventually, all these tests, rather than measuring potential for achievement *became* the measure of achievement. More to the point, the tests that had been designed to sample education now came to determine what was taught. Large publishing houses began selling textbooks and other consumables to elementary schools with drill units that carried a remarkable resemblance to IQ subtests. Thus began a self-feeding, circular relationship.

There is, however, a more promising alternative view of intelligence.

Multiple intelligences

For a while, there were voices arguing that intelligence was better conceived as a set of possibly independent factors. Later findings from AI (Artificial Intelligence) research, developmental psychology, and neurology, prompted investigators to put forth the view that the mind consists of several independent modules or *intelligences*. In the 1980s, Howard Gardner formulated his theory of multiple intelligences (1983; 1993), in which he stated that people use one or more of at least seven (more recently eight and even nine) relatively autonomous, intellectual capacities to approach problems and create products. In many aspects, Gardner's views run against entrenched notions of pedagogical psychology. Gardner's seven intelligencies are:

1 Linguistic intelligence (as in a poet);

2 Logical-mathematical intelligence (as in a scientist);

3 Musical intelligence (as in a composer);

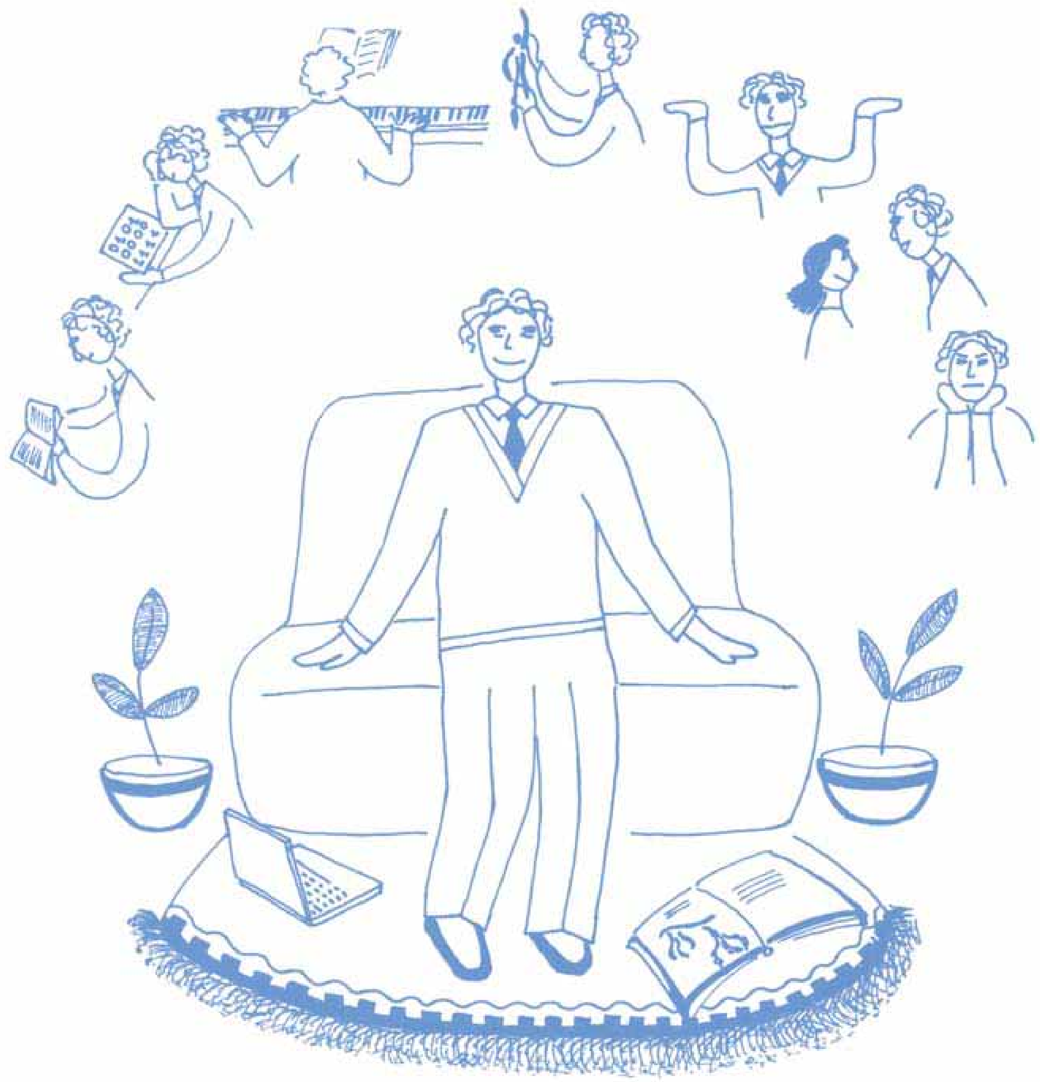
4 Spatial intelligence (as in a sculptor or flight pilot);

5 Bodily kinaesthetic intelligence (as in an athlete or dancer);

6 Interpersonal intelligence (as in a salesman or teacher);

7 Intrapersonal intelligence (exhibited by individuals with accurate views of themselves).

What is important to the present discussion is Gardner's stress on the fact that a particular intelligence cannot be conceptualized independently of the particular context in which an individual happens to live, work and play, and the opportunities and values provided by that milieu. For example, Bobby Fisher might have had the potential to be a great chess player, but if he had lived in a culture without chess, that potential would never have been manifested, let alone actualized.



The time has come for schools to incorporate a wider array of mental processes and activities into the learning process. Whereas traditional classes have been dominated by the spoken and printed word, the new classroom should practise a multisensory enhanced learning. Indeed, as long ago as 1920, Vygotsky's work (see Vygotsky, 1978) showed that a child's cognition and thinking, to a great extent, relied upon the manipulation of material objects used as tools as well as societal surrounding.

Intelligence is always an interaction between biological proclivities and opportunities for learning in a particular cultural context. Vygotsky and Papert would agree wholeheartedly with Gardner; and Papert would especially emphasize the role of immediate surroundings, allowing and prompting the child to investigate and consciously transforming purposely its material, energetic and informational aspects and components.

Unfortunately, as Gardner and Papert never miss the chance to point out, the school system, which largely reflects yesterday's Western culture, teaches, tests, reinforces, and rewards primarily only two intelligences: verbal and logical-mathematical. These two intelligences are, of course, essential for effective functioning in a knowledge society, but so are all the other intelligences. Not only have the other kinds of intelligence been highly developed by gifted graphic artists, dancers, musicians and writers, they may also be pathways to learning for many poorly achieving students who do not learn in *legitimate* ways. For everyone, developing these multiple intelligences increases creativity, flexibility of thinking, and the broad cultural and humanitarian background that enriches living.

The resources for this enrichment are typically thought of as material artifacts like books, textbooks, and computer files. However, other individuals are part of one's distributed intelligence also. Most workers do not depend exclusively on their own skills and understanding; rather, they assume the presence of others in their work environments. This view is brought home vividly when one considers an office or a classroom that is being computerized and has access to the WWW.

Testing abilities

Another approach to the nature, structure and functions of intelligence(s) has been proposed by Robert Sternberg, who suggests three kinds of intelligence:

1. componential, which is assessed by many traditional tests used today;
2. contextual, which is the source of creative insight, and
3. experiential, which is the *street smarts* of intelligence. (Sternberg 1985; 1988)

Sternberg's latter two intelligences do not often show up on traditional tests, and are not always highly valued in the classroom, since curious and creative students and those who learn by doing tend to take up more of a teacher's time and attention. Such students are later valued in the adult world, however, as creative thinkers and process-oriented employees who often affect the bottom line in productive ways.

Sternberg feels that some people's major intelligence is in the traditionally tested/graded area of *critical thinking* (generating new innovative thought and connection), and that people who are able to make things really work for them out there in real life are *contextual thinkers*. Sternberg's theory is too complex to be elaborated here in full detail. One of its outcomes is the Sternberg Triarchic

Abilities Test (STAT), which is divided into nine multiple levels for different ages, and described as suitable for kindergarten through college, as well as for adults.

In contrast to conventional tests, STAT yields separate scores for componential information processing (analytical ability), coping with novelty (synthetic ability), and (as a separate score) automatization and practical-intellectual skills. Equally important, the test puts more emphasis on the ability to learn than on what has been learned, and verbal skill is measured by learning from context, not by vocabulary. The test also measures skills for coping with novelty, whereby the examinee must imagine a hypothetical state of the world (such as cats being magnetic) and then reason as though this state of the world were true. In yet another example, STAT measures practical abilities such as reasoning about advertisements and political slogans, not just decontextualized words or geometric forms.

In fact, as Sternberg himself admits, STAT is not immune to prior learning, and nor is it *culture-free*. It is hardly thinkable to design a test that would satisfy all the considered demands. Intelligence is always used in some particular, usually rather restricted context, though it is highly desirable to have this context as wide as possible.

Sternberg's theory differs from Gardner's. However, the two theories are also highly complementary. Sternberg makes us strongly believe that intelligence needs to be seen as a broader and more complex construct than both authors declare, and the field is open to any experienced, thoughtful, and enterprising teacher eager to make her or his own contribution to the common educational cauldron.

Multiple ways and conditions of learning

We must exploit universal features of the child's (and the adult's) personality to a greater extent. Children have a natural interest and curiosity about the internal and external world, and an eagerness to communicate and to play, making collections and ordering items, creating unexpected and aesthetically significant objects. The basis for human development – habits and skills for lifelong learning – should be established early in primary schools.

Appealing to both sensory and symbolic smarts

It is widely accepted today that it is not enough for students to understand and learn fragmented information. It is equally important for students to understand the context, meaning, and gestalt of topics as well. The objective, sterile environment in many schools actually inhibits learning. Learning is also unlikely to occur when students harbour negative feelings about an instructor, peers, class work, or have difficult personal issues. The traditional classroom must be replaced by rich, stimulating, accepting, warm, and responsive surroundings. Sylvia Farnham-Diggory agrees:

> Both children and adults acquire knowledge from active participation in holistic, complex, meaningful environments organized around long-term goals. Fractionated instruction maximizes forgetting, inattention, and passivity. Today's school programs could hardly have been better designed to prevent a child's natural learning system from operating. (Farnham-Diggory 1990)

As most teachers know, students labeled *weak* or *slow* often turn out to be bright and skilful when confronted with something that is personally appealing or challenging outside the classroom. Though these students have difficulty learning in school, they often excel at making, fixing and operating tangible things: gadgets, bicycles, motors, electrical circuits, complex mechanical devices, arcade games, VCRs, various kinds of contraptions and even imaginary objects. These children are usually identified as having trouble with the *symbolic smarts* that form the core of schooling.

It is not surprising that the traditional school focuses on what *weak* students cannot do, and does not see them as possessing virtuoso *sensory smarts* in some fields. Instead, it sees them as failing to perform, or not meeting the requirements. An ideal teacher will appeal equally to symbolic and sensory smart students with a view to bringing these two kinds of knowledge into active and fruitful collaboration.

For example, a computer with a Logo environment and LEGO extensions allows students to build working systems out of tangible blocks, using their hands as well as their *theoretical* mind, in the form of symbolic expressions on the monitor screen. When students are encouraged by teachers to reflect on and confront the differences and similarities that emerge as they move across materials, sensory modalities, and kinds of descriptions, it helps them to create mental bridges between *action knowledge* and *symbolic knowledge*. Previously hidden aspects of hands-on constructions are revealed. Children who build both real world and virtual world structures begin to see the resemblance among working systems. In making the resemblance explicit, they liberate and make easily understandable the basic principles that the working systems share. (Resnick 1997)

Visual cognition and creative thinking

Visualization of inner mental imagery and the outer graphic presentation of reality in pictures, drawings, diagrams, lists, and charts is a fundamental part of creativity, discovery, invention, and problem solving. The vital importance of visualization is affirmed by the fact that a surprisingly large proportion of the human cortex is devoted to vision and visual analysis, and that the bandwidth of the visual channel is greater than that of any other sense. In many instances, the eye, and those parts of the brain that process visual information, lay the foundation for enhancing conscious thinking, which in turn, grows from our preconscious mental activity.

To take full advantage of the capabilities of the eye, the goal of visualization should be objectification. This means that a phenomenon, inherently visual or not, should be represented as having form, colour, texture, motion and other qualities of objects.

Inductive thinking relies to a great extent upon the human ability to visualize on this preconscious level. Major portions of the visual system including the retina, the structures ascending to the visual cortex, and parts of the visual cortex itself fall into the preconscious category. More powerful than a supercomputer, these functional entities relentlessly perform information-processing miracles, creating a three-dimensional, coloured visual environment that our conscious self exploits in a logical way to serve definite practical purposes. Our conceptual images are constantly being analyzed at a preconscious level, and produce useful data for establishing spatial relations, making conscious representations and building plans. In other words, the outcomes of these subliminal mental activities become the elements, tools, and procedures of rational thinking.

This is where computers make an enormous difference. When we visualize with the help of computers, video camcorders, and big-screen high-resolution projection, we restructure a problem situation so that more of it can be processed by the preconscious part of our brain – the visual system that is our silent partner. In this way, consciousness can be devoted to higher levels of critical analysis and synthesis. Especially interesting, are virtual worlds that model nothing but themselves, as do many games, chess among them. Nevertheless, by representing spatially the system of abstract relations between chessmen on a chessboard, a professional chess player can think in images. Similarly, it is also possible to visualize on a computer screen the spatial interrelations of elementary predicates and, consequently, to represent complex formulas of predicate logic (Bederson and Shneiderman 2003; Card, MacKinlay, and Shneiderman 1990; Friedhoff and Benzon 1989; Rieber 1995).

As a kind of modelling, visualization has many aspects. One is aesthetic-emotional. For example, nobody will deny that visualized mathematical objects and functions can be aesthetically beautiful. *Fractal* animated cartoons, captivatingly spectacular and shown on TV all over the world, have already inspired works of fine art (even if not eternal masterpieces). Beyond any doubt, it is precisely because of their aesthetic components that such themes as chaos, fractals, and the like, have become so popular in academic mathematical courses.

Another aspect of visualization-as-modelling is, as in the classical art of painting, selecting and making visible essential traits of the object or phenomenon depicted. By forcing us to pay attention only to what can be seen and perceived by the eye, visualizing helps to impart a meaning to a problem and makes it easier to find its solution. In the simplest case of a virtual constructor used to build interactive models of physical phenomena, we may get a picture of an ideal experiment, which is mathematically correct within a set degree of accuracy.

Using a similar learning environment under a teacher's guidance, the student can trace all levels of abstractions in modelling. For instance, there could be genuine physical objects and processes (say, a carousel on which children have a ride), material (LEGO-like) models, videotapes, computer simulations (virtual realities), graphical representations of processes' characteristics by co-ordinates and velocities within a set referential system, and symbolic modelling by algebraic and differential equations.

Heterarchy and changing pedagogy

New pedagogy is based on the opposite of the traditional classical hierarchy – that is, a *heterarchy*, a term that depicts a system in which each working element or agent is equally ruled by all others. This means that, while learning, these agents communicate or talk to each other, exchanging messages filled with related information. In this system, there are no simple linear chains of cause and effect, but more and more cross-connected rings and loops.

Behind the dazzling variety of new theories, methodologies, and working approaches to learning, one can detect several underlying patterns, or fundamental principles and practices that seem perennial. Re-christened in modern idioms, these principles are referred to as poly-sensory, experiential, project-oriented, constructivist, and connectionist.

Constructivism

Constructivism, a term introduced by Jean Piaget, asserts that the knowledge acquired by students should not be supplied by the teacher as a ready-made product. Children do best by creating for themselves the specific knowledge they need, rather than being instructed in what they must know. Seymour Papert later found that such things would happen especially felicitously when learners are engaged in constructing something external or at least shareable: a sand castle, a book, a machine, a computer program (Papert 1980). These kinds of activities lead to a model of learning that involves a cycle of internalization of what is outside, then externalization of what is inside, and so on.

Connectivism

This mode of collaboration paves the way to *connectivism*, or *connectionism* or *connectivity of knowledge*, which Seymour Papert professed after many years clinging to logical step-by-step constructivism. According to his later views:

> The deliberate part of learning consists of making connections between mental entities that already exist; new mental entities seem to come into existence in more subtle ways that escape conscious (i.e. step-by-step) control ... This offers a strategy to facilitate learning by improving the connectivity in the learning environment, by actions on cultures rather than on individuals. (Papert 1993)

Papert asserts that conceptual connections between a given notion or phenomenon and a wide array of other notions and phenomena are often helpful in gaining a more substantial understanding of a subject under study. Rather than passively receiving ready-made facts, notions and opinions, students acquire advanced skills and knowledge by solving problems in their immediate surroundings that they consider personally meaningful and emotionally exciting.

In the days of sweeping global changes, training for a particular skill or job must endow the trainee with an ability to be re-trained and self-retrained. It follows that we believe the concept of mass training to be short-sighted. Constructivist education must take command even in vocational and elementary schools, and a trainee must become a true learner. The priority is not the transmission of particular knowledge and skills from teacher to taught, but the development of the ability to acquire these by students on their own. All this, of course, is facilitated by new technologies of education.

For many decades, the polemics surrounding educational reform have vacillated between two points of view: those who favour a progressive, child-centred form of education, and those who prefer a return to a more structured, teacher-directed curriculum that emphasizes basic knowledge and skills. Today, however, a growing number of educators adhere to an alternative trend, intended to reconcile these opposing stances. This latter view is the theory of a collaborative community of teacher and students, focused on a dialogue and co-construction of knowledge. Such an approach helps resolve the conflict between traditional *instructive* teaching and *constructive-connectivist* autonomous learning. In this, too, ICT are playing a key role.

Project method: learning by designing

Among many proposals for revitalizing general education, the *learning projects* advocated and corroborated in the last century by John Dewey, Jean Piaget, Jerome Bruner, and Seymour Papert are among the most promising. The trouble is that such learning projects cannot be introduced in a form that the traditional school recognizes: as a ready-made set of precisely defined tasks or particular objectives, operations and procedures given in advance. Instead, these projects have to be found, discovered, invented, or designed in the course of a class.

To benefit from this project method, both teacher and student must acquire some generic skills rarely taught in an ordinary school. Different authors call these skills the *design mode* of thinking and looking at things, the *designer's approach* to problem solving, and *designerly ways of knowing*. Mastering and exercising those skills would eventually lead to the formation of *The Design* (or Third) *Culture*, mediating the much-lamented rift between the two cultures of C. P. Snow – the Techno-Scientific and Humanistic-Artistic.

We invite readers to take part in detecting, unearthing, and cultivating the elements and principles of design in learning. This involves conceptualizing its problem situations, generating options, making choices, conducting mental experiments, finding acceptable solutions, and evaluating probable outcomes before actually implementing them. From this standpoint, design can be seen as an innovative intellectual technology waiting to be converted into a powerful technology of education.

For a start, let us consider what makes, or might make, school learning really interesting, attractive, and successful for students and teachers alike.

True teachers do something more than just transfer information. In receiving any source-material, teachers make it a part of themselves by re-exploring, re-interpreting, and re-constructing its form and content in a personal way. Examining the phenomenon of inner speech, Vygotsky (1986) pointed out that a child, assimilating a certain notion, re-works it, and during the process of re-working, expresses the peculiar features of his own thought. V. S. Bibler, a contemporary Russian philosopher and educator, adds that in inner speech, an individual transforms the socialized and relatively static images of culture into a culture of thought, dynamic and personal. (Bibler 1996) Especially interesting is Bibler's remark that in such cases an inner speech becomes future oriented and serves as "the mould for *creating new*, *non-existent yet*, *but just possible* images of culture". We could say that true teachers act as designers of both the «images of subject-matter» to be presented in the classroom, and the tools to be used by students in order to transform given images into a personal culture of thought. In this way, they enable students to develop their own abilities to learn.

By initiating communication and interaction regarding the design of the learning process, a true teacher learns no less than the students, who, in fact, are teaching themselves and one another. These and other aforementioned theoretical concepts of modern reform-minded pedagogy can be summarized in the practical recommendations in the final sections of this chapter.

TEACHING STUDENTS TO BE LEARNERS

If you are a devoted schoolteacher in the 21st century, what should be your essential mission, main professional calling, and foremost pursuit?

The answer is in the wind: to teach students to become good learners.

What does this mean, functionally, as well as structurally? We would argue that a good learner is someone who is always alert, attentive, perceptive, responsive, and ready to be pro-active in grasping, digesting or assimilating a knowledge, skill or competence. This is true from kindergarten, elementary, middle school and high school, through years in college or university, and in all walks of adult life. If you really devote yourself to raising and tutoring such characters on a daily basis, let us consider some necessary theoretical cornerstones, technical requirements, and organizational prerequisites.

To make a good learner out of every student in your class, you may pick up and try tentatively alternate trails, tools, and methods. However, we have good reason to believe that it is wiser to adopt the strategy of what might be called *the way of new schooling*. Here it is in a nutshell:

1 Find at least two or three (better five to seven) colleagues at your own or other schools, who share your strivings and are willing to collaborate either close by or far off (e.g. via email exchange) to develop a project.

Teachers who wish to pursue such a mission must intermittently transmute themselves into part-time researchers, designers and constructors of the new educational technologies. The argument for collaboration is simple: there is no one who can instruct contemporary teachers authoritatively and unilaterally on what to do in all particular, unprecedented and unique circumstances. Therefore, teachers must think and act on their own while trying to weave a web of interconnectedness and mutual assistance with as many concerned and knowledgeable people as possible.

2 Show students a variety of optional activities from which each is asked to choose a few that are challenging, alluring, and suitable to them personally.

3 Provide a friendly environment, materials, and tools with which students can tinker freely, if only by imitating by example.

4 Encourage students by means of informal conversation and discussion to exercise playfully their explorative curiosity, adroitness, and inventiveness, coupled with developing an awareness of what they are doing in the broader cultural-educational context.

At this preliminary stage, both students and adults learn that a teacher can be not only a mentor, tutor, or instructor, but also an older, experienced, skilful, and responsible playmate with whom it is easy to communicate and interact.

5 Introduce some simple and attractive structured games with strict, explicitly defined rules relevant to the topic under study, and invite the students to play to win.

Now students learn that the teacher can initiate them into new kinds of competitive play and games that enable students to demonstrate their wit and mental adroitness.

6 Make students aware that their success in playing these goal-oriented games depends upon their willingness, and acquired ability to observe – not break! – conventional rules they have accepted by mutual agreement.

In this way, students learn how to turn the limitations and restrictions imposed by these rules into a springboard for reaching higher levels of resourcefulness and ingenuity. They come to treat the teacher as a respected game-leader, whose mastery they are hoping to equal some day.

7 Devise a series of more complicated, project-oriented games that are related to the consequent themes, topics, and tasks in various subject matters and implying a collaborative rather than competitive approach to problem solving.

At this stage, the game has been imperceptibly transformed. In fact, it will no longer be clear to anyone whether it is still a game or a cognitive, productive activity of a serious kind. Students, in their turn, will become more and more involved in mutually supporting, intellectually and emotionally rewarding teamwork for exploration, research, designing, testing and implementing their discoveries, inventions, and solutions, while seeing the teacher as a partner in real business and a competent master of the craft.

TEACHERS AS MASTER-LEARNERS

Schoolteachers must revise their positions, leaving behind the status of the omniscient one who has all the answers. Instead, genuine teachers will become advisers and learning facilitators. Influence and credibility will accrue to those who not only *instruct* but also *construct* and *connect* in front of the class, that is, by skillfully doing something they may really be interested in, prompting students to learn how to do it by their own minds and hands.

Possible learning projects are as diverse as assembling and operating model cars and toy trains, building and decorating puppet homes, writing and printing prose and poetry via a word processor and desktop publishing, turning out pop tunes with a synthesizer, drawing simple animated cartoons, or cracking the codes of mediocre computer games in order to make them more challenging.

The main goal of this construction and connection should be, of course, the acquisition of knowledge and skills required by the curriculum, plus the experience of being in control of one's own process of collaborative teaching and learning.

As a matter of fact, the authority of teachers can be re-established on the basis that they possesses three interconnected kinds of mastery:

1 Mastery of Doing – one can do a lot, but not everything, and can do more in cooperation with others.

2 Mastery of Learning – one is not the only source of information but can teach how to find alternative sources.

3 Mastery of Collaboration – one can multiply results by joint work with students and other teachers.

It is worth noting parenthetically that the word *mastery* has the double connotation of power to control one's surroundings, and wisdom to use it appropriately. Teachers of the 21st century are called to restore the dual meaning of mastery in its completeness.

EMERGING NEW SCHOOLS

Is it conceivable to embody the new pedagogical theories, methods, and recommendations espoused in this chapter within the established framework of general education? If so, why have all these brilliant ideas not been introduced everywhere? The reason (besides the inertia of educational system) is this: these ideas are technically unrealizable where the textbook, blackboard, pencil and paper are still the only external tools for instruction and learning. ICT give schools a chance to vanquish these seemingly insurmountable obstacles.

We look in the next chapter at typical schools of today equipped with affordable ICT equipment, and see what kind of positive changes can be made in the learning environment.

4

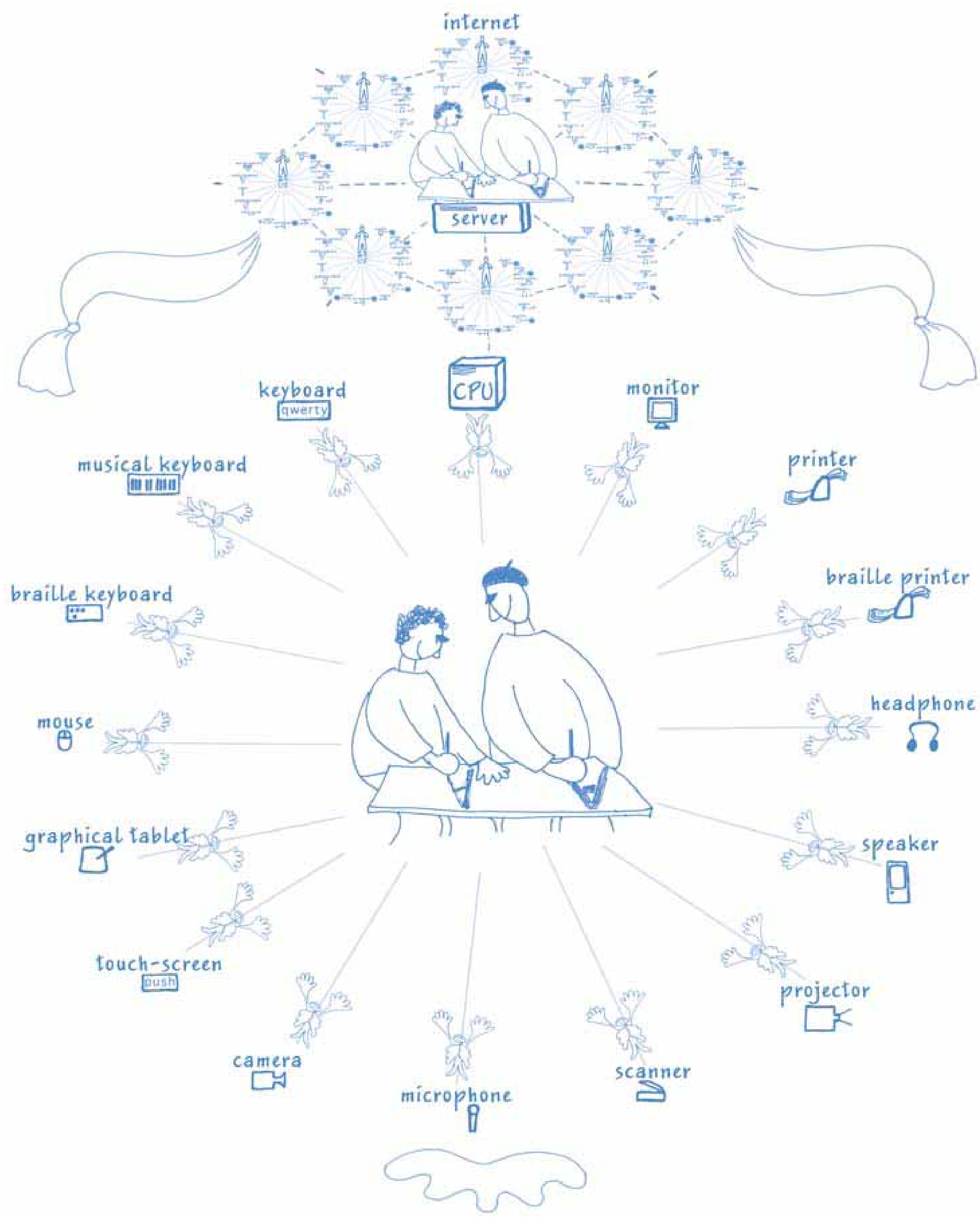
ICT IN LEARNING AND TEACHING

The latest ICT allow radically new opportunities for human activities. How will education meet these challenges? Today, in the wider society, most people who need to add up a bill use a calculator. Most texts are written and read on a computer. However, such activities are not paralleled in our schools. Even in developed countries, most children use a calculator or a computer at school only occasionally (and calculators are used more often in science classes, than in mathematics lessons). We observe a digital divide, therefore, between the world at large and the schools teaching children to enter it. Of course, we do not underestimate a further digital divide between countries and between communities within a country. In the near future, it will be possible to turn to a mobile handset to answer most problems and questions on school tests, and to receive oral or written help or advice automatically (without even using a qualified expert) in a few seconds. What does all this mean for the future of education? What does it mean for the school finding itself in such circumstances?

NEW POSSIBILITIES

Do what we are not already doing

The fundamental error that many educators commit when they consider using ICT is to view them through the lens of their current practice. They ask, “How can I use these technological capabilities to streamline or improve what I’m really doing?” instead of asking, “How can I use ICT to do things that we are not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already doing?" By their very nature, ICT call for innovation. It is about exploiting the full capabilities of technology to open new perspectives for both teachers and students.

At the same time, it is unwise to ignore traditional styles and models of learning as well as ideas from the past that were not implemented in the mass school but were precious exceptions.

Therefore, we need to start with things that we are already doing, but consider them anew.

Schools of tomorrow seen through schools of today

One way to introduce ICT into school education is to observe schools without computers and see what opportunities arise to facilitate various educational activities by using ICT. Starting from that point, we can recognize that schools without computers are different, and that different applications of ICT are possible. We discover that some teaching and learning activities can be advanced much more than others. Then we can reconsider how desirable different activities are from the point of view of educational goals for individuals and society. Eventually, we can discover, or imagine, certain new forms of learning beyond the reality, experience, and vision of past centuries.

Of course, it is an absolute requirement to begin in small steps experimentally and to have a program tested by broad practice before recommending it for others. Nor is it necessary for a school to have acquired all high-end ICT in order to feel the benefits and impact of ICT on practice. Every improvement in technology almost immediately finds its application in the practical work of some teachers in schools and broadens educational horizons (as we emphasize, not in just a technological sense, but in the sense of enrichment of human activities).

ATOMS OF LEARNING

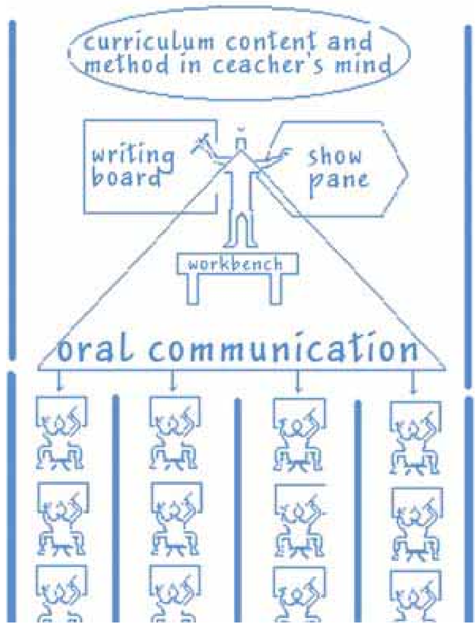
In this section, we overview the simplest elements of learning and teaching and describe how the ICT, detailed in Chapter 2, can contribute, and why this contribution can make teaching and learning more effective. We analyze well-known situations and indicate all sorts of changes made possible by ICT.

Immediate oral communication

Lecture

Let us start with an important general example of a traditional mode of teaching-learning – a lecture. In the classical model, the teacher speaks and students listen. As in other cases of oral communication, the teacher relies heavily on such extra-verbal components as the tempo of speech, voice dynamics, facial expression, gesticulation, and body movements. These *tools* of rhetoric are used to express something, to transfer information (including emotional and aesthetic), to hold the attention of students, to impress and to engage them.

Teachers control the situation by looking directly at students, tracking signs of interest or absence and other emotions, and using this (mostly non-verbal) feedback to tune up their part of the communication. Feedback from students can be oral or written (in the form of notes handed up to teachers). Depending on the teacher's rules, students have a chance to speak during a lecture or at the end of the lecture only. This communication is usually limited in time and form; students mostly ask short questions. Teachers can also pose questions to the students, sometimes expecting a non-verbal clearly visible response from all of them such as "Raise your hands, please, if you know who Newton is".



What makes the lecture an important and useful mode of learning and teaching are the following:

- One teacher addresses many students and this is economical for providing modern schooling to the whole population, not a selected elite only.
- Teachers can react to students' behaviour in a limited way by adjusting their talk, and individually in a more limited way, by addressing a short message to a specific person and giving other kinds of feedback.

- Within limits, students can solve problems of misunderstanding and unsuccessful communication by asking questions.

The disadvantages of the lecture model are that it:

- encourages passive learning;
- affords limited individualization; and
- allows limited extra-verbal communication with a limited use of the senses and channels of human perception.

What technologies are involved in the traditional lecture? And what extensions of these do we have, or can we expect in the future?

The major information channel for the lecture is the aural one. Of course there is human voice technology – you can be trained to project your voice to an audience of 100-200 people, or more. A special design of the auditorium can contribute to a lecture. Microphones, amplifiers, and other equipment can improve loudness and even acoustic quality of human speech. Students can also use microphones while asking questions. Installing audio equipment for a lecture in a large room or hall can be a sophisticated task that requires a professional. One of the important issues here is to place loudspeakers (the sources of sound) in a way that students get the impression the sound is coming from the lecturer – to amplify mutually two different channels of information, not to confuse them.

Using a microphone requires proper positioning – not too far so you cannot be heard, and not so close that your voice is distorted. Surprisingly few people today manage to use a microphone properly, and so good sound in lectures is not so common.

Radio microphones are useful when it is desirable to move around in a room or to pass the microphone between discussion participants. An option of using small and light wearable microphones simplifies the problem of proper positioning but also requires simple technical knowledge.

The loudspeaker is not the only option for amplification. We can supply every student (and the teacher, if needed) with headphones. Signals to headphones can come via wires or a wireless network. A popular application of headphones is in simultaneous translation, which is not widely used in schools, although often encountered at international meetings of researchers and others, and could be imitated in schools.

Visual component of oral communication

The visual component of lectures is as important as in other cases of oral communication. At the same time, new ICT technologies are changing face-to-face lecturing. For example, in the case of bigger audiences, the speaker's face and figure can be captured by a video camera, magnified, and projected onto a screen.

In some subjects, an important component of the lecture content is given by visual images other than that of the speaker. Most lecturers traditionally use a blackboard or an overhead projector. In some subjects like mathematics, this appears inevitable. A broader list of typical visual components includes:

- key points of a talk indicated in a written form on a chalk- or white-board;
- the derivation of mathematical formulas, as well as mathematical formulas accompanying discussion of physical, biological, or economic issues;
- chemical formulas and other, less important formalisms;
- drawings and conceptual diagrams;
- all kinds of ready-made images (artistic paintings, photographs, book pages, technical drawings, maps) as illustrations; and
- real objects and processes (like experiments), if they are big enough to be seen by an audience.

ICT extensions of this communication are based on projection technology. As noted in Chapter 2, a projector can greatly increase the size of an image if the ambient light is not too bright.

Now, a combined computer and projector open new possibilities and generate a new culture of oral communication accompanied by screen images.

In comparison with pre-computer lectures, this new technology allows the following:

- The speaker can combine pre-recorded images (including text) with images made during a lecture. Pre-recorded video fragments can be included accompanied by sounds if needed.
- Images of real objects obtained via cameras can be downloaded to a computer or connected directly to the projector.

This technology allows for clearer visualization, and saves time the lecturer needs to spend on writing. However, lecturers need to be aware of the following:

- Text on the screen should be economical.
- *Sans serif* fonts (like this) are easier to read on screen.
- Do not read the text from the screen; screen text is a tag to what you are saying.
- Leave a little time for an audience to absorb each slide.

It is often helpful to give listeners a printed copy of all slides from a presentation to take away with them (for example, these can be printed six slides per page).

The natural screen image of a lecture usually calls for two screens: one to enlarge the figure and face of the speaker, and the other for the visual-textual part of the speech.

Of course, digital video images can accompany transmitted and recorded lectures, placing the lecturer's face or figure on part of the screen, and surrounding it with other material, or simply using the lecturer as a background voice.

Communication between teacher and student

Today, teacher-student communication – whether face-to-face, live, synchronous, or online – is carried out within strict temporal and spatial boundaries. These boundaries are largely imposed by the school timetable with its:

- sub-division of the class period into a lecture or demonstration (sort of one-way broadcasting) and consecutive conversations with individual students that may or may not involve attention and participation from the rest of the class; and
- sharp divide between in-school and out-of-school time, where no direct communication is supposed.

Assuming the school's information space is digitized, these boundaries might be easily crossed, or broken down technically. However, to get there, we first must face two new problems. The first is how to weave a reliably functioning network, or a web of mutual interconnections between all persons involved. The other is to allow enough time for each network user to communicate adequately with other network users.

Communication initiated by students

A good teacher needs time and space to respond to students' questions, statements, raised hands, looking through the window, smiling, and other types of verbal and non-verbal behaviour, as well as to encourage their participation in group activities. This vital human component is not thrown out by the use of ICT. Indeed, we should think about elements of the teacher's role as being supported or automated by ICT. At the same time, ICT make possible new forms of teacher-student communication. As we know, email has revitalized letter writing, while voice mail and answering machine sometimes help when wanting to say something that is hard to do face-to-face.

Students' speech

Microphones and screen presentations can help students even more than teachers. There are many cases where a student who is considered weak in oral communication develops eloquence, and even confidence, by using screen presentation support.

Answering teachers' questions

One of the drawbacks of teachers' questioning in the traditional school is that usually only one or two students are allowed time to answer during each class period. Computers, however, can record written and even oral answers by all students on the timeline.

Electronic digital lectures

Let us consider now the opportunities provided by modern ICT for broadcasting lectures with synchronous participation of learners. Synchronicity supports the organizational discipline mentioned above. A new opportunity provided by computer technology today is bi-lateral interactivity. Students can answer the questions teachers ask, and ask them questions, too, all in a written form, from wherever they live. Naturally, a CD and regular textbooks can accompany the course of such lectures.

In such situations, the major advantage of a digitized lecture is the breadth of the audience it can reach. The physical limitation here is the time zone. Of course, the number of actively participating students cannot be too big, but they do not all need to be in the same place.

For the teacher, the digitized lecture has other advantages. First of all, the lecture can be transmitted online (synchronously with the real event) to many places at once. Feedback is possible in the form of written notes sent by students. The teacher can show on screen the face of a student who has asked a relevant question. Other students asking questions that might be anticipated can receive standard answers generated by assistants or automatically.

The second option is to distribute a recorded lecture in canned form, recorded on DVD or videotape, or via the Internet. The advantages of these media are:

- mass distribution, multiplied audience;
- better quality text accompanied by pictures, and additional readings; and
- availability anytime, anywhere, at a learner's convenience.

ICT (printing and recording) make a considerable difference in delivering lectures. Nevertheless, certain advantages of new technologies can also be considered disadvantages. For example, the requirement to meet face-to-face at lectures at a given time is a discipline that organizes the process of learning. Sometimes, it is a welcome discipline for a professor! On the part of students, the obligation to make written notes provides additional support for concentration and memorizing through kinaesthetic activity and provokes online re-thinking of the content.

In some regions and communities, many people already receive general education by means of radio or magnetic recordings. Sometimes even a combination of radio transmission or playing a record and simultaneous face-to-face tutoring is used to good effect in general education. Many people learn foreign languages while driving and listening to audiotapes. The next step is TV and videotapes. These add something to the traditional lecture: you can see lecturers at their best time of the day, the voice is clear, the face is close, and so on. Eventually, we arrive at the HDTV and DVD era, with its picture-in-picture format.

Is it possible to learn using combinations of the abovementioned media? The answer is *yes*. Is it helpful to add to lecture text materials and video-audio records? Again, *yes*. In other words, the traditional lecture is not dying. It is in danger of becoming more interesting.

Reading

The lecture is not the only way to channel curriculum information to students. Students read textbooks and go to the library on the teacher's advice. They visit museums and art galleries, and take excursions to see natural scenic attractions, great architecture, and other monuments of historical and cultural interest. Each visit may bring them an enormous amount of information that helps them to assimilate, enrich, and enhance the knowledge they get from the formal curriculum.

ICT can be of great help in providing multimedia information on objects and sites of such kinds, especially those that are located too far away to be observed directly, or inaccessible for other reasons. At the same time, we should remember that understanding implies active participation on the students' part: the transformative inner reworking of content delivered. As Jean Piaget loved to say, to understand is to invent.

Reading is an important activity of the traditional school. Books contain not only written text, but also visual information. Good reading in the traditional sense implies, of course, good formal memorizing though this is becoming less important. It also means active reading – making notes, writing out quotations, and looking for and into other works referred to. Reading is part of the whole business of constructing a personal information space by the student. A process-intensive way of acquiring a particular piece of learning content can even help a student memorize it by heart.

Electronic digital textbooks

Let us consider the best possible canned (recorded) course of lectures. They have good video-audio quality, and may be accompanied by a printed text since the substitute of text-on-screen is not completely satisfactory today. Typically, lectures and accompanying textbooks can contain educational material of an advanced level or some optional information. In a lecture, this material can be relatively short and marked by a special introductory statement. In a textbook, it can be printed in smaller letters or placed in an appendix. In both cases, the options are limited, because of limits of material time and paper. In the case of electronic media, these limitations do not exist.

Modern electronic digital media such as DVD can accommodate hundreds of thousands of text pages. The digital lecture-textbook can thus be organized to display different levels of material, both in the sense of depth and breadth of subject matter and in the sense of how it is presented to the student. It can contain references or links to other related material whereas the lecturer has to point to the blackboard or show a slide again. The digital video textbook can also provide links to another part of the course, or to another course, or indeed to any piece of information available in the school library and beyond on the Internet.

Broadening the range of materials used in classrooms

ICT are making it increasingly easy for teachers and students to have access to a broader range of materials than they can use in the classroom. The simplest example is the copying machine, which allows teachers to make copies of articles, charts, or printed instructional materials from outside sources and to distribute these among students. Supplementary computer tools such as scanners or digital cameras allow teachers to bring in outside sources, enter them into a computer, and customize assignments. For example, teachers can bring a timely article from the morning newspaper into class, scan it in minutes, and have their students work on rewriting, editing, or adding other research material to the story on the same day. Encyclopedias, art collections, atlases, and other reference books in a less expensive, and less space-consuming electronic format will be of everyday use in classrooms.

Already, in many schools, students can browse interactively or conduct electronic searches in CD-ROM databases, encyclopedias, or other reference work. Thus, the new technologies allow access to a broader range of instructional resources. They also offer students the opportunity to learn how to use electronic tools to access information and develop research skills in solving problems.

Web learning

Learning on the Web is one of the most promising and rapidly developing areas of ICT in education. At the same time, it is one of the most complex psychologically and socially controversial fields. There may be problems for some students with sensitive topics like sex education, narcotics, and political or religious extremism. Some voices are calling for compulsory technical restrictions imposed on accessing objectionable sources of information.

There are also hybrid situations where content can be pre-loaded onto a learner's computer and integrated with other dynamic environments on the Web. Automated and human responses can be mixed.

Writing

Speed of writing

Most people, and especially children, can type faster than they write, and they can learn to type faster than learning to write. For smaller children, writing in clear calligraphy is a major problem. ICT allow students to learn communicative skills independently of the kinaesthetic ability to write. Writing in a clear script is important, but this can be trained separately, while students get on with the excitement of communicating.

Writing as designing and constructing

Two Russian proverbs reflect the irreversible character of some oral and written communication:

> *A word is not a sparrow – you can't catch it after it has fled.*
> Nearest English equivalent: *A word spoken is past recalling*.
>
> and
>
> *What is written with a pen cannot be cut out with an axe.*
> Nearest English equivalent: *What is writ is writ*.

In oral communication, this reality will probably never change. However, one of the beauties, and the banes, of the modern computer is that you can change whatever you want at any time. Moreover, changes are reversible. You can keep all versions of a paper or manuscript, and changes are traceable. In other words, the written object is close to the ideal in its flexibility. Indeed, perhaps for the first time in history, it takes less time to make a change than to think of it.

In education, this means that students are free of the horror of fatal errors. They are in a more adult position: if you, the Teacher, do not like it, I, the Student, can change it. As a result, the whole culture of writing in school is changing.

In the traditional school, the student writes an essay and the teacher offers corrections and advice. The student often pays little attention to these corrections and even less to the advice. In a very few cases, the student may argue with the teacher but there the story ends. In this new model, students with a little effort have a chance to improve the text, rewriting part or parts of it, and resubmitting it to the teacher for comments, and then taking these into account. The resulting evaluation of their work will take into account the efforts to improve it. A student's work can be reviewed, and undergo formal and informal evaluation, by peers and also by different teachers like the science teacher, the language arts teacher, or the ICT-coordinator, all at the same time.

The process of producing written work can be sub-divided into three main phases: *prewriting*, *writing*, and *postwriting*:

1. Prewriting includes deciding on a topic to write about, brainstorming one or more topics, reminiscing and selecting the most significant aspects, and gathering and organizing thoughts about how the writing is to be structured.
2. Writing is the creation and the online reading and editing of an emerging text.
3. Postwriting comprises rewriting, stimulated by immediate editorial feedback from the teacher (and classmates), then meticulously checking for spelling and grammar, correcting the syntax, revisiting and changing word sequences. It also may include any other editorial and publishing work down to physical manufacturing the book with stitching, sizing and binding. Students write better when they have a real audience for their written work and when the teacher offers them convenient channels and mechanisms for reaching a wider reading public via, for instance, the Internet or school newsletter.

The writing process described above is not confined to fiction or non-fiction literature. It is archetypal for all kinds of activities related to design and implementation of any project – be it erecting a skyscraper, establishing a bank, or writing and debugging a computer program. Above all, this circular procedure is a powerful conceptual tool for truly efficient perception, thinking, cognition, and learning. By its very essence, it implies discovering, inventing and creating meaning, which can be expressed, presented and embodied in fleeting spoken words, in corporal movements, gestures, and postures, in graphic symbols, in hand-made articles, or in heavy-duty mechanical devices.

In general, writing in schools today is becoming closer to other types of design and construction activity, including top-down planning using outliners, using pieces of old work, and different stages of finishing.

Spelling

Another feature of ICT that is changing radically the art of essay writing is spelling. What once took considerable effort has become a trivial task with automatic spelling checkers. The immediate adoption of spelling checkers would be too radical perhaps for the school system in certain countries. However, to ignore them means adding one more item not of direct use to academic knowledge to be acquired. Therefore, we should rethink the goals and values of education, and place more critical thinking, perhaps more language construction, and more teaching about computer tools into the writing process.

Hypertext

What distinguishes inner speech from outer speech in oral or written form is its non-linearity. Thinkable objects are not linear, but a network of associations. This is reflected in the hyper-structure of texts, which with printed-paper, can be represented in the form of footnotes, endnotes, and bibliographic references. To teach children hyper-writing is not difficult because for them it is more natural than it is for adults who have learned how to linearize and discipline speech.

Multimedia

The multimedia information object is a much more natural thing in a child's inner world than a text. ICT provide tools for making these objects visible on paper and on screen, on the Internet, or for a classroom performance. After students make multimedia objects, by writing texts, collecting information from the Internet and encyclopedias, inserting drawings and photographs made by themselves, adding speech and sound, it becomes natural to share it with other students and the teacher. This hybrid activity can be important for mastering cognitive skills.

Cooperation and sharing

Students sitting together in the same classroom, or communicating over a long-distance network, can do cooperative writing. This is important, first, as practice for joint work and, secondly, for life, but is generally neglected and sometimes even suppressed in the traditional 20th century school.

The ability to copy and email information objects like essays, pictures, and presentations gives students the opportunity to share information easily with, and receive comments from, others outside the classroom. These other audiences could be teachers of different subjects, other students and friends, parents and relatives, local community, a pen pal, or (by posting it on a website) others in the world.

Essay writing and citation

There is a downside when it comes to the influence of ICT on essay writing, as many teachers have discovered. Essay writing on different subjects and topics became more and more popular as a reaction to standardized tests in the 1990s just as the Internet was becoming easier to use. Within a few years, teachers found they were reading more and more identical essays submitted by students. Students had discovered a new, easier way to *write* an essay – find it on the Internet.

This kind of cheating led to a whole system and even a commercial business of counter-measures to provide teachers with tools to detect copying. Are these countermeasures good or bad? There is no question that copying without acknowledgment is bad, but the solution is not to police minute phrases that might be parallel. There is an opportunity here to introduce students to appropriate ways of citing the work of others, which after all is the basis of scholarship. What teachers should look for is independence and originality of thought. The reaction to a discovered case of copying without citation should not be that this is a deadly sin but rather “Good for finding some relevant information. Now tell me what YOU think about this topic and include a correct reference link, please”. A disagreement over the printed word is rewarded and becomes a basis for critical thinking and evaluation.

Transforming oral speech into written form

The classical work of taking dictation can be radically transformed as well by ICT. A teacher may ask students to use their computers to make a sound recording of their oral text, recited as normal speech, and then to transcribe it. Each student may play the recording back while listening through individual headphones as many times as they need to write down every word. The advantages of such dictation are obvious:

- All students work at a pace that suits them best.
- A teacher can trace the progress of each student in detail by simply connecting to the screens of students' computers.
- When teachers see a student finish a task, they can provide more oral text, either as live dictation through a microphone, or as a pre-recorded sound file. In this mode, every student in a classroom can move along at their personal pace, not interfering or competing with other students for the teacher's attention and time.

The next stage would be to give the class an assignment to make an abstract, or synopsis, of the teacher's oral text. The major difference here is that students themselves choose the object of transcription. It can be a TV discussion or a movie segment, a political leader's speech or, in the best case, something recorded by students themselves – a teacher's introduction, a street interview on the environment in the school area, or Grandma's story of her childhood. Digital technology provides a comfortable environment for this activity: to slow down the tempo, segment and mark the texts, see the speaker, and so on.

Group discussion

In the new paradigm, there is much more space for class discussion with many students participating. Such discussions can start with a text or a hypermedia piece presented by teachers or students. The major points expressed by the participants can be recorded and presented on screen. Thus, the evolving discussion is visualized. Moreover, short video-clips of speeches can be made and presented on screen in the form of icons. The teacher can participate as moderator. The discussion is not limited in space and time: it can go on the Internet as live chat or be delayed. Prerecorded and recorded discussions can be sent as an immediate-to-all or delayed message. At the same time, screen-written images help to make discussion more systemic, effective and disciplined.

Teachers' notes

Notes can help teachers say what they intend to say. Teachers can even prepare the whole text of a lecture in written form, though this is usually less effective than a lecture without notes or with a limited use of them because it narrows the channel of communication (including eye contact) and misses out on feedback. At the same time, short notes in the form of key points or key words presented to the audience beforehand can make a lecture easier to follow.

Students' notes

Notes made by students can help them remember information provided in lectures. What can ICT add to this situation?

- Notes can be taken by students on computer unless it is too noisy to type during lectures.
- Notes can be made before the lecture by teachers and distributed to students with extra space to add hand-written notes, or notes in electronic form.

Autonomous automatic recording

Finally, an entire lecture may be recorded on camera.

Working with a recorded lecture, students can produce written text with the needed level of detail and additional links, screens of the presentation placed properly, a still image of teacher's face, or audio-video fragments at the most dramatic points.

With ICT, no teaching and learning activity need be left without audiovisual, graphic, and alphanumeric documentation, including students' work, comments, drawings, and written reports. Instant access to these records allows prospective students to discover that they can master these new conceptual tools and to control and improve their own work performance. The earlier they begin, the better.

Overview

From an educational point of view, writing priorities have changed in all aspects, including calligraphy, spell-checking, and oral input.

- Writing is not textual: it is now multimedia composing.
- The products of writing can be made accessible to a large audience, including, by means of the Internet, anyone in the world who might be interested.
- The process of writing can be collective, involving the author's classmates, students from other schools, editors, and many others.
- Text is not static, but in constant development.
- Computers can help in speed and quality of writing.

While acquiring basic writing, reading, and communication skills, students become accustomed to various ways and means of acquiring, transmitting and using information and knowledge needed to achieve concrete goals. Presenting one's thoughts and collected information to other people can be the final stage, for instance, of a history or science project, or the major part of a journalistic activity, or an initial part of a fund-raising campaign.

Science experiments and observations

Certain fundamental concepts of mathematics and science are given to visual realization (modelling) that ICT are well suited to reproduce. In such cases, students can freely manipulate objects representing these concepts on a computer, experiencing in different ways the dynamic relations between their actions and the visible behaviour of the model.

For example, by connecting to a distant sensor, a computer can display a graph showing the measured distance from the sensor to a moving body (for instance, the body of a student walking back and forth along a wall in the room). In this case, the walking student can see the correlation between their moves and the graph. They can follow a given graph pattern or explain in words what was happening at this or that moment previously recorded and seen on the screen. Or they can tell what one should do to produce some particular pattern on the screen. Then, they can command or advise another student or the teacher how to walk with eyes closed.

For another example, the concept of thermo-conductivity can be demonstrated and explored using a temperature sensor and thermal perception of the human skin.

In the world beyond school, computers automatically collect data and control real three-dimensional material objects and processes. Similar applications can be exciting and educational in school contexts as well. Children's construction kits can include interfaces, input sensors, and output devices such as motors and lights. A computer program can control a model constructed by a child. Even more importantly, students can write the computer program. Furthermore, there is a *programmable brick*, which has input connectors to which sensors can be attached. This piece of integrated hardware and software also has output connectors to which motors, bulbs, and sound signals can be attached.

One can input a program into the brick memory. The program is written on a regular computer and then transmitted to the brick by wire or infrared ray. The student can design a robot, for example, and plan its behaviour in a chosen environment. Then the robot is made out of LEGO blocks and the description of the robot's behaviour, in the form of a computer program, is put into the brick's memory. Modern bricks can interact with each other and also with computers via infrared connection.

Of course, this needs software support to provide interfaces between input-output devices and the computer, as well as between computers and human beings. This software can include algorithms for data processing and visualization. The computerized science lab combines many types of sensors with software to collect, store, analyze, and graphically present data. The sensors can be wired to computers or transmit data wirelessly; data can also be accumulated on a small device called a data logger for later transfer to a computer.

School use of general and professional applications

As the experience of schools tells us, many students are ready to use conventional application packages. With them, students can tackle tasks similar to those facing adults; they can write, draw, edit, make a database, and create a spreadsheet or screen presentation.

We note several special types of software that have clear and productive use in schools (even elementary schools):

- CAD (Computer Aided Design or Drawing).
- GIS (Geographic Information Systems).
- Data analysis packages.
- Project planning software.

Needless to say, professional applications of CAD are too complicated for beginners. Moreover, since they offer a broad spectrum of ready-made tools and instruments, they make it impossible for the student to create a tool for a particular task – an activity that is immensely rich and valuable from an educational point of view. However, there are school versions of these applications that have special features that allow for more simplicity and openness of use.

GIS allow a student to use existing maps and to put more information on them in the form of a word, picture, or hyperlink. The teacher can use the map, without accompanying text, to check students' memorization of geographic names. There are software products, called *timeliners*, that can be used in learning history in much the same way that digital maps help in learning geography.

The computer as an instrument for data collecting, analyzing and presenting in visual form is an important tool to balance technicalities of paperwork upon data (e. g. environmental or social) and understanding their meaning.

Project planning software is another way to visualize, in this case the process of design and implementation of a student or team activity, including a learning activity.

Virtual laboratory

In a computer-run virtual laboratory, we can stage experiments that imitate real ones. A student or teacher can construct shapes, choosing, pointing, moving, indicating numerical parameters by sliding an indicator, or by direct input. They can also change settings easily. The student or teacher then simply pushes the START button and the experiment begins. The parameters' values can be organized in tables, and their data can be presented on graphs. For example, we can see colliding molecules and create a graph of the distribution of their speeds. It is important that students conduct many experiments and get their numerical results quickly, so they can produce their own hypotheses and verify them.

In solving algebraic equations, students can use graphs to verify their calculations and transformations of the formula. In models of atomic and molecular structures that simulate individual particles' interaction, students can track emerging phenomena such as temperature, pressure, states of matter, phase change, absorption, latent heats, osmosis, diffusion, heat flow, crystals, inclusions, and annealing; chemical phenomena such as exchange energy with bonds, chemical equilibrium, heat gain and loss in reactions, explosions, stoichiometry, colour, spectra, florescence, and chemiluminescence, plasma, surface tension, solutions, hydrophilic and hydrophobic molecules, conformation, binding specificity, and self-assembly.

Working with microworlds can help a student to construct knowledge of real world subjects (physics, geometry, economics, environmental studies) as well as of abstract mathematics. The applications in secondary schools have been very successful, especially in geometry and physics. *Geometer's Sketchpad*, for instance, is a computer environment in which students do their own mathematical research, set up experiments, state hypotheses, and prove or refute them. This software has radically changed the perspective of how to treat a school subject that has remained fundamentally unchanged for 2000 years. A similar product for teaching physics is called *Interactive Physics*. There are algebraic manipulation packages of a similar kind. Aimed at learning geometry and physics in middle school, these programs are successfully used for preparatory purposes in primary education as well.

New software allows children to construct any combination of simple machines, which helps in the development of reasoning skills, including spatial, causal and design thinking. Another important class of microworlds is tutoring environments for typing, spelling and foreign languages.

Mathematics teaching today is in a paradoxical situation in that every mathematical problem can be solved by a personal computer. Therefore, as in other subjects, we are forced to rethink how and why we teach the subject. At the same time, ICT are a boost to experimental mathematics, allowing students to draw graphs of functions, and check relations in geometrical configurations in which parameters as a point position can be changed by dragging a mouse.

Organization of the learning process

Guided learning

A software program can incorporate a teaching strategy, which gives pieces of information and tasks to students and interacts with them. The simplest versions of this approach are referred to as drill and practice. In some cases, this works quite well – for example, typing tutors. In other cases, a large investment is required to produce a quality product (as in foreign language teaching). Nor are all products equally effective or appealing to students' imagination. One extreme case is the *electronic textbook*, which is still generally a paper textbook brought to the computer screen.

Tests and examinations

Traditionally, testing (assessment) gives teachers and students feedback and serves as a basis for certification of learning and teaching as well as a gateway to further education or a job. There are obvious reasons why testing procedures should be simple in a technical sense (so as not to require much time from the person who conducts it) and objective (in order not to depend on the test-giver's attitudes, views and conditions). This has led to so-called multiple-choice tests, which can be extended in new ways by ICT.

What are the advantages of such tests? Clearly the procedure is quick and objective; results are stored automatically in the computer and are available via a network. Problems can be chosen from item banks, and even generated randomly as specific cases of a generic parametric problem. The problems themselves can be presented in a multimedia form. Extensions of multiple-choice tests are possible, for example, including blind-maps, grammar exercises in the form of filling in blanks, and written dictations. Computers now recognize oral speech, so they can check the answer to a foreign language exercise, for example.

What more can an automated testing program do? A computer can certainly record all interactions with students. To make it economical, we can limit this recording to all text inputs and some oral (through microphones) and kinaesthetic (with a mouse) inputs. The problem, then, is how to evaluate these moves and how to react to them.

There is a big temptation to automate the process of interaction. This is a model of so-called *programmed learning*, developed long before computers came into existence, and then revitalized in the form of *Computer Aided Instruction* (CAI). In some cases like touch-typing, this works perfectly. It can work also in the process of learning technicalities of certain ICT environments such as text editors, CAD packages, or search engines. Open inquiry technicalities can be learned in the same way by, for instance, varying structural parameters of a system under experimental investigation and registering the changes in its functional behaviour.

Can the inquiry itself be monitored and controlled along similar lines? This is the Philosophers' Stone, sought for years by researchers and prophets of ICT in education. A definitive answer has yet to be found.

Nevertheless, it is clear that automation of much of a teacher's work is possible. We can outline some features of a system that supports interaction between student, teacher, and information environment:

- Scripts of interaction are available, understandable, changeable and able to be constructed by educational researchers, textbook writers, willing teachers, and students (the most controversial and the most exciting opportunity). Records of interaction are also available in an understandable and structured format.
- The system of script writing and use can be integrated into general school information space, and into specialized learning environments used by a student or teacher. The system can monitor and control a student's use of tools, resources, search and observation instruments. Students can thus be restricted in using calculators, spell checkers, equation solvers, historical databases, Internet space, looking inside living organisms and chemical molecules. Strictly enforced, this can make learning in a rich ICT environment similar to the 20th century school.
- The system provides tools for organizing usual and complementary educational activities, including classwork and homework, essay writing and submitting, word-problem solving in mathematics and physics, conducting virtual experiments in the setting provided by a textbook or a teacher, or constructed by a student.

Elements of this complex information system are already in use in schools worldwide. While they are not the final solution for everyone, they may be useful in almost any school. For example, any school can use a computer to record test scores, to place individual assignments on a school website , or to collect students' works via email.

Diaries and portfolios

A prerequisite for success and progress in learning is keeping diaries of the learning process, as well as portfolios of texts, drawings and other artifacts produced in the class or workshop. Teachers and students should make their diaries and portfolios as encompassing and detailed as practicable.

Furthermore, because innovative pedagogical proposals are always restrained by a lack of time, diaries and portfolios save a great amount of time that would be spent gathering information, or on labour-consuming routine operations. In general, as we have seen in other areas, ICT allow teachers and students to achieve their particular educational objectives within the standard school time periods, or even faster.

Information resources for education

We can summarize the categories of components and activities that are integrated in the school information space. These are:

- Information sources
- Information instruments
- Control tools

Individual pictures, texts, sound recordings, maps and other information objects, and their collections constitute *information sources.* They can be properly described and open for use by all students, teachers, and textbook authors. They are numerous – currently millions of items are organized for education.

Information instruments are much less numerous. There are dozens, not hundreds of them. Most are produced in the long process of labour-consuming programming, debugging, testing, and revising; some were developed in the form of code open for further improvement by anyone interested.

Control tools for the learning process implement specific content and didactics in school practice. Many of them are made with the help of certain generic instruments.

MORE COMPLEX EDUCATIONAL EVENTS

In this section, we consider more complex educational events and how ICT can be used as successful learning tools for these.

Approaching the new literacy

Literacy is the ability to vocalize a written text, or, conversely, transcribe an oral text. This skill is overvalued in the same manner as mechanical numeracy – the ability to do calculations mentally or with a pen and paper – because often we measure overall learning success of students by the speed of their oral reading or mental calculations. ICT can do these operations much more quickly and with better quality anyway. At the same time, higher-level competences are becoming more and more important. Priorities are changing. The new literacy – the system of basic linguistic, logico-computational, and communicative skills and competencies, needed to deal with internal and external technology – is a latchkey that opens the doors of subsequent stages of organized teaching and learning. An introduction of ICT in schools gives students an impetus to learn, unlocking many doors of perception and cognition.

We now discuss the roads by which young learners can approach the new literacy and the role of ICT.

Oral language learning

The first, and in many cases the best, teacher is a child's mother and other family members. Different processes are involved in learning the mother tongue, like imitating, asking questions and claiming help. A child also learns a lot just by moving, seeing, listening, smelling, and falling. An adult's presence and interaction is not always critical. Interaction with the physical world, observing and imitating an adult's behaviour, can sometimes be enough. Usually a computer cannot add much to, or substitute for, the development of this process of understanding physical reality. However, it can provide a considerable part of what an adult does in connection with a child's learning activity. Every object on a screen, for example, can pronounce its own name when touched. If an action or an event is occurring on the screen, the participants can explain what they are doing. Today's computers can even ask questions, hear and correct answers.

Student universe

The simplest and most convincing application of ICT in school occurs on the very first day, when students tell a computer (with the teacher's help) their names. Now it happens in written form by typing: in the near future, it will be done aurally, in combination with keyboarding. The computer will memorize the names and even print out corresponding name badges. The badges are given to students (teachers and other adults at school have the same kind of badges), who can now read their teacher's and each other's names. Reading becomes practically important!

In the next step, the computer asks for more information about each student. The computer then prints out a series of pages. If you cut and bind these together, you will have your first address book containing the names, addresses, and telephone numbers of all your schoolmates.

At some point, you start to collect your family memoirs – photographs, stories, letters, and combine these with additional findings in electronic archives. This kind of project may be extended indefinitely.

Written language learning

Learning how to write a language is a combination of learning to:

- produce letters and their combinations – words on paper with brush, or crayon;
- write words in the correct spelling;
- write down oral speech; and
- generate a text based on your understanding of what you are going to say.

Traditionally, children learn these activities sequentially. In fact, the last step usually comes too late and the natural urge of the child to communicate freely is thwarted (mostly by grammar exercises). Eventually this delay reduces students' interest in oral communication as well.

Many-faceted texts. Evidence shows that young children do not think of texts or writing strictly in print-linguistic terms. Given their first notebooks in school and let loose to do their own thing, they draw pictures and invent symbols; some write letters, some make their names, words, even phrases. Almost all declare they can "write and read already".

At the same time, modern children are bombarded visually by many other *written texts* that actually have many facets not reducible to just words. Among these are labels, trade marks, colour codes and graphic instructions on cereal boxes and candies, table games and hi-tech toys; traffic signs, comic strips, TV-station and car logos, mailed advertisements, and many other impressive things of similar kind, which children can perceive, bring with them into a classroom, and reproduce here and there on paper without much hesitation. All these are part of a child's communicative world and cannot be cast aside and ignored as anomalies of no interest to educators.

Small children are especially inventive and productive when given a computer with a multimedia (text/graphic/sonic) editor. Very often they produce dynamic pictorial presentations and even animated stories with a soundtrack of an oral enactment, with photos or drawings of the main characters, and with commentaries on their action and behaviour. More often than not, picture drawing precedes writing, and the accompanying oral commentaries are usually more complete and elaborate than a fragmentary and abruptly written text.

However, once all this is done, a teacher can ask students to transcribe their spoken words using the keyboard, or just picking up needed letters from the alphabet shown on the screen. Even if the first attempts do not produce real outcomes, students can always try again, and in time make small, noticeable improvements.

Nomination. An important part of learning a mother tongue and the world is students' creations of their own language. In a more scientific way, we can say that giving names corresponds to the elementary act of cognition through discovery, as well as gaining control over what has been named. While teaching names of objects, letters should not necessarily be written in calligraphy; they can as well be handled as pre-fabricated units and posted beside, above, or underneath the drawn images. Students can be encouraged to *read* their texts in both a sequential and non-linear *omni-directional manner*.

As soon as students start writing in this way, it ceases to be something non-situational and isolated, taught compulsorily and out of context (the plague of so many elementary grammar classes). It becomes storytelling, re-enacting of the plot of a play, a thought made visible, and a communication of created meaning to others – activities already familiar and pleasant for all children. The itch to read aloud what has been written amid this enthusiastic exchange occurs immediately, providing powerful motivation to continue this joyful and collaborative learning-by-doing.

Virtual reality of words and meanings

Let us reminisce for a moment about how the ABC is typically taught in an ordinary school or kindergarten. The teacher typically demonstrates a set of different large-sized characters, usually paired with pictures of objects designated by the words that start with the same letters. Then, the teacher writes them on the blackboard, or parades three-dimensional plastic or wooden items taken from a bag and places them upon a desktop. The student composes them into a scrabble-like series of two- and three-letter words (*on*, *at*, *or*, *dad*, *mum*, *boy*, *sun*, *sky*), and reads each word aloud. After the demonstration, each student is given assorted cardboard printed or wooden block characters with an assignment to build and, hopefully, write the same words on the paper. As any teacher knows, this is by no means a simple enterprise, if only because of the physical obstacles involved.

The teacher's immediate objective is to keep 25 or 30 students' attention. In practice, only the children sitting close to the teacher's desk perceive the intended message in its entirety. Those in the back rows inevitably miss relevant points, shades, and nuances. They also are more susceptible to distractions and deviations, ambient sights and sounds, the temptation to whisper with one another, or just falling into a daydream. Now and then, a boy or a girl may start to scream desperately and appeals for help because something went wrong. In coping with these encumbrances, teachers strain their voices and exaggerate their gestures, and periodically call by name the students who need to be woken up. And teachers barely have time to look over their shoulders at what students are scribbling in their workbooks, and they have even less chance to consult with or instruct the more confused and perplexed ones.

When it comes to evaluate their progress, teachers can hardly summon each student to the blackboard before the class is over. The rest are inevitably relegated to the daily homework of copying letters – an assignment requiring mechanical repetition and devoid of any cognitive effort or emotional reward.

Now assume you are giving the same lesson in an ICT-networked classroom. Each student's desktop is supplemented with an enveloping VR-helmet, gloves and other paraphernalia, which these pre-literate children have already mastered technically by playing computer games. This time you invite them to put on the gear for an adventure in *The First Grader's Grammar Cyberspace*. In a moment, students see and hear via their private high-resolution multimedia displays the image of a teacher sitting or standing in equally close proximity to each student. There is a *live*, synchronous, or online digital closed-loop translation of what you actually do on the black or white (magnetic) board, or upon your desktop with three dimensional characters as you compose words and read them aloud during the aforementioned letters and words demonstration.

If students do not comprehend or miss something, they can raise their hand and ask the teacher to explain or repeat it once more. All the other students can hear and see the question and the teacher's response. After the introductory stage, the teacher can decide whether or not to continue the explanation individually.

When the demonstration is complete and an assignment is understood, all the students see and hear the teacher offering a set of characters to compose and copy the exemplars. This time you switch from *live* online communication to a prefabricated program. Now the children have the visual, aural and tactile impressions of dealing with genuine material objects, which are in fact only interactive virtual realities. Each student starts to work independently offline and soon discovers that the characters encountered have some intriguing features. When touched, perhaps they spell their own names; when two or three are joined together, they pronounce the word (if rightly composed), or emit a protesting sound (if the combination is wrong). When students place two, three, or more words in a row, they hear them pronouncing the whole sentence. The students do not need to ask a teacher whether a word or sentence is right or wrong, the program makes this clear, and students can move on to the next part of the assignment – practising writing the words they have formed by manipulating tangible characters. The students see a virtual sheet of paper and a pen or pencil-like stylus, which they grasp, and start to write, seeing scribbles appearing instead of expected letters.

Everything written on VR-paper with a VR-stylus is instantly erasable (though it is actually being saved as backups for later evaluation). Thus a student can have any number of tries until a more or less satisfying result is reached. Students can address a teacher orally or have an online conversation to share their doubts, troubles, feelings, and thoughts concerning the task, without disturbing classmates. The teacher, meanwhile, can watch on a multi-screen display what is happening on each student desktop simultaneously. If you want to focus on Mary's or John's desktop, you can enlarge their particular screen. You can whisper in their ear something encouraging, soothing, reproaching, or enlivening, as well as giving them a helpful hint while remaining unheard by anyone else. You can also point with your finger to this or that character or word, even grasp it with your hand to change its position.

If you think it desirable, you can address the whole class and draw everybody's attention to a typical or rare and interesting problem under consideration, and then let them return to their individual work. At the end of a class period, the teacher has the full records of every student's activity, and thus will be able to track and evaluate what they have accomplished.

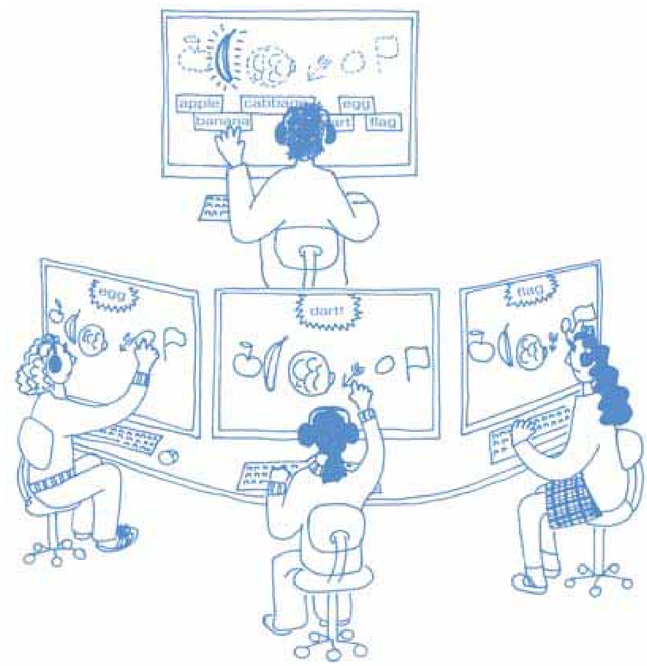
Learning oral speech by the deaf

The visual and tactile representation of speech patterns can be instrumental in teaching deaf-mute children to speak. Students are given a visible or tangible sample pattern of a particular vowel, consonant, syllable or word. They are asked to articulate corresponding sounds while watching on the display what is being actually produced by their vocal apparatus. Next they are requested to compare and evaluate achieved results against a sample. If considerable discrepancies are detected, students are asked to repeat the procedure in order to improve their articulation until it is as close an imitation as possible of the sample.

Foreign language learning

As is well known, the most effective method of learning a foreign language is to live in the country concerned. This is the basis for a natural approach to learning languages even when one cannot be physically there.

A pre-ICT version of this approach was called *immersion* and consisted of a series of role-play games controlled by a qualified teacher. CD-ROM versions provide similar simulated interactive environments with sounds and images. The ability to have written, and, sometime in the future, oral interaction is the principal element of this concept.



The Internet can provide different levels of presence, starting from email communication to virtual museums and videoconferencing to (in the future) online virtual reality where a large number of students will be able to collaborate on global educational projects, where foreign language learning will be combined and supported by on-screen automated translation.

Design and construction in learning

Here are the main stages of a designing-constructing cycle:

- defining needs, goals, requirements and limitations of a design;
- building up teams, defining working plans;
- writing down specifications and drawing first sketches and blueprints;
- making models and prototypes;
- checking and verification of specifications; and
- making the final model.

In a school setting, ICT are a base for a simplified CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) system, in which a technical drawing on a computer screen can eventually be transformed to a real object made of material that is simple to process, but we extend the design concept well beyond this and so we continue with some other representative examples.

Microworlds

Agents to be taught by students

As we have emphasized, the computer is a universal information-processing machine. In particular, a computer with adequate software can simulate and present on screen different real or imagined settings and environments. These are sometimes called *microworlds*. Microworlds are helpful in different applications.

First of all, microworlds are effective and popular tools for learning fundamental aspects of computer programming, especially structural programming. Ideally, they establish a direct connection between a student's semi-formal planning of activity in the microworld and its implementation. The link between the two is called a special *Agent* or sometimes *Executor*.

An Agent is capable of performing a set of commands given by a child – for example, to move across the screen, make turns, and leave a trace of its movements. In a sense, the child is *training* the Agent to perform quite complex tasks.

A specific example is the *Robot-in-Maze* microworld. The maze is a labyrinth usually within the boundaries of a rectangular grid. An Agent called Robot has a limited set of elementary sensors such as the ability to *see* or *feel* a wall in front of it and a repertory of predetermined actions like, for instance, *head North*. A large set of tasks can be given to the student. The first tasks begin simply with, for example, the maze as an empty rectangle. Further tasks can bring a student to sophisticated issues of structural algorithm design. Students can immediately see the execution of their plan on the computer screen.

Another well-known example is the *Turtle* microworld. An Agent called, and looking very much like a, Turtle can move forward any specified distance, turn to any specified angle, draw geometric figures, and change shape and colour. The most important example of a Turtle microworld is the Logo family. In fact, some of the Logo languages combine the idea of microworlds with general applications components (text, graphics and sound editors) and general office applications.

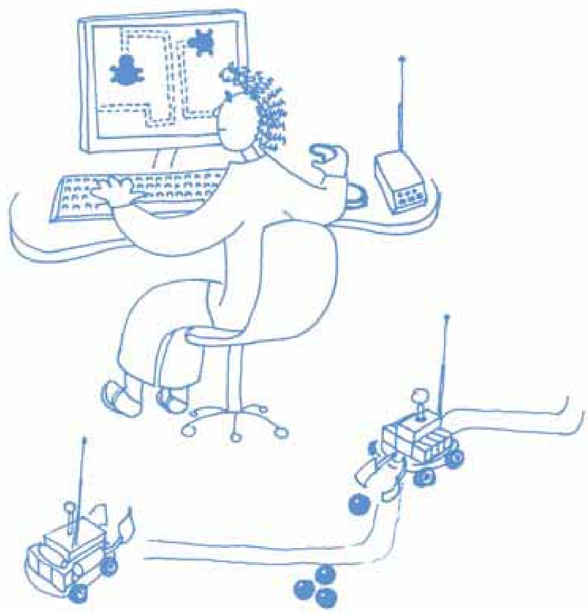
Let us describe the main educational advantages of microworlds, which are evident even in the most basic forms.

Being in command motivates learning activity

A teacher begins by showing students how an Agent can be made to move by typing commands at a keyboard or by clicking pictorial icons and setting sliders, determining kinds, directions and parameters of the Agent's movements. For example, typing FORWARD 100 makes an Agent move in a straight line a distance of 100 Agent *steps* of one millimetre each. Typing RIGHT 90 causes the Agent to pivot in place through 90 degrees. Typing PENDOWN causes the Agent to lower a pen in order to leave a visible trace of its path while PENUP instructs it to raise the pen and leave no trace. Students need to explore a great deal before gaining mastery of these steps but the task is engaging enough to carry most children through this stage of learning.

Since learning to control the Agent is like learning a language, this activity mobilizes the student's expertise and pleasure in speaking. Since it puts the student in charge, it also mobilizes the student's expertise and pleasure in commanding. To make an Agent trace a square, you walk in a square yourself and describe what you are doing in the language of programming. And so working with the Agent mobilizes as well the student's expertise and pleasure in motion. It draws on students' well-established *body-geometry* as a starting point for the development of bridges to formal geometry.

Students' first goal in this microworld is not to learn formal rules but to develop insights into the way objects move in space. These insights are described in the Agent's *language* and thereby become *programs* and *procedures* for the Agent. For example, suppose a child wants to *teach* the Agent to draw a house. First of all, it is necessary to make an Agent draw a square, then a triangle on top of it. A teacher may provide helpful hints on how to write a proper command. A more complicated problem arises when it comes to making an Agent that can move only along straight lines draw a circle. A teacher does not provide answers, but rather introduces students to a method for solving, not only this problem, but a large class of others as well. This method is simply to *play the Agent* – that is, for students to move their body as the Agent would move on the screen in order to draw a desired pattern: when you walk in a circle, you take a little step forward and you turn a little, and you keep doing this until the full circle is completed.



It is worth noting than such geometry is not insignificant. Thus, students are led imperceptibly to an intuitive grasp of physics, calculus and mathematical modelling that is used in many other areas of contemporary science, technology, and humanities alike.

Building learning aids

No less important, by *teaching* the microworld's Agents, students learn to design and construct their own software tools and aids to be used in learning the *hard* items of the standard mathematics curriculum and other subjects. The first project of this kind was successfully implemented in the mid-1970s, and the corresponding methodology has been used ever since. The story is described by Seymour Papert in his book, *Mindstorms* (1980), and goes something like this.

A class of fourth-graders had just started to study fractions and, as often happens, many appeared to be rather slow in grasping the issue. Traditionally, in such cases, the backward ones would have been given additional instruction and tuition. Now, instead, they were equipped with Logo microworlds (already familiar to them) and invited to find and develop some means for explaining and teaching fractions to themselves and others who needed help. They were also provided with seed ideas on how to think of themselves as collaborators in the project and its data collection, processing and reporting.

Each day, before going to the computer, the students spent 5 to 7 minutes writing their plans and drawing their designs for making, comparing and analyzing fractions, presented as graphic objects in their personal designer's notebooks. Then they worked at computers for 40 to 55 minutes individually or in groups, having full freedom to choose which concepts they wanted to teach, what the sequence of their lesson should be, and what instructional games, quizzes and tests to include. The amount of time spent at the computer was limited in order to fit the project into the schedule of the class and of the school.

Over the course of four months, the class had developed several programs on teaching fractions that were diversified conceptually and quite useful in classroom practice. Judging by pre- and post- tests, students' ability to work with fractions, as well as with the microworld proper, had increased considerably. They had not only discovered that *fractions are everywhere* and can be easily explained in their *becoming*, but also acquired fluent ability to do other problems by manipulating fractions. The very integrating of mathematical concepts, drawing, constructing and writing made these disciplines mutually supportive.

The possibilities of microworlds in education are limitless. Supplemented with specialized tools, they enable students to create environments for the entire range of learning activities, from producing animated cartoons on central themes of literature and history to conducting scientific exploration and constructing advanced industrial machinery. Above all, they enhance students' general competence and confidence in active learning.

Artificial life experiments

Students can make working models of living organisms using blocks from construction sets that have motors, gears, wheels and sensors. After connecting their artificial creatures to a computer, they can write computer programs to control the behaviour of their animals. As mentioned above, the programmable brick – a special microprocessor included in the construction set – allows the model to function and move independently of the desktop or notebook on which the controlling program was written.

Such systems allow the images on the computer screen to be realized in three-dimensional, tangible form. Through these activities, primary school children can explore and discuss some of the central themes of Artificial Life research. This is not merely a scientific and technological topic, but a set of extremely powerful ideas that include emergence, bottom-up design, and system-oriented thinking. Giving children access to the forefront of modern science is, in general, an effective learning strategy. When children sense that they are involved in a new and dynamic adult enterprise, they eagerly invest themselves in the process.

This project on artificial life can proceed in three-dimensional physical modelling and computer-screen versions. The students start with simple, easily understood rules or units, and study how complexity emerges from interactions among elements. Moving from simple to complex, from concrete to abstract, is just how children learn in everyday playful surroundings. Furthermore, they learn best when they are building and inventing things that they believe in and care about (which is why living things are useful at this stage).

For example, a youngster might program an animal like the screen turtle to move toward a light, but change direction if it bumps into any obstacles. Children can explore how artificial organisms behave in different *habitats*, and how they interact with other creatures. In addition to changing an animal's program, students can change its habitat. For example, a student might try adding more lights, or making the lights flash, and then wonder whether the animal will behave differently in the new environment. Which light will it seek out? Why? Children can also change the hardware or software of the animal and see the difference in its behavioural pattern. In many cases, such experiments pose a question of basic similarities, as well as distinctions, between organic and mechanical organization.

By the same token, students are not restricted to artificial animals: they can also build and program various machines, from vehicles to robots. This system-oriented approach influences the way children think about systems of all kinds: physical, political, and economic. But the most important thing is how this process influences the way students think about themselves as human beings who create systems, not the other way round.

Basic music composition

Let us consider an example of a design and construction activity in music. Traditionally, music classes in elementary school concentrate on performing and not on composing. On the other hand, children aged 7 and up, with no knowledge of formal musical notation, can learn how to create simple melodies in one or two years by operating a computer with an audio synthesizing and editing microworld used as a medium and tool for structuring and shaping the *material* of sound. A microworld of this kind provides a choice of musical notes in the range of seven octaves and commands that set a desired pitch, volume, and duration to consecutive strings of sounds (and pauses). Further, the sound can be given the coloration of any particular instrument and be made to simulate the sound of an ensemble of several instrumental voices.

The student's musical work with the computer is divided into three stages with well-defined features: a musical scrawl, musical sketch, and musical project.

The first stage is indiscriminate exploration: each student produces various sounds for the sheer pleasure of it and without paying much attention to their quality. After a while, they limit themselves to playing with low or high sounds, with an emphasis on the duration of the sound. Then students can start to build small melodies that lack formal structure since they are chosen at random. At this point, they are usually more concerned with the duration of the melody than with the actual sounds. At the end of the first stage, students select the sounds they like most, name them, and create melodies based on these sounds. In this way, they learn to program the sounds and melodies in a natural way, because they have a need to do so. They start to exercise auditory perception and to pay more attention to pitch than to duration.

In the second stage, students usually discover short sounds by chance and they start to glimpse the effects of sounds' parameters (pitch and duration). Thus begins a period of discriminate exploration of the musical microworld as they reflect on each sound's qualities. The sounds are not chosen at random anymore. Duration is the most prominent sound quality at this stage. The development of sound appreciation is apparent in the expanding selection of meaningful words that students use to name, not only sounds, but their created melodies as well. Once students begin to play with short sounds, they then tend to regulate the quantities of sound. For example, they discriminate between long and short sounds, while associating them with numbers; they combine closed notes, or make repetitions of two or three sounds, which results in sketches of a more formal organization where, for example, the first and last sounds are the same.

The third stage brings mastery of this particular music microworld. Here, students match the commands of sound qualities with desired pitch and duration. They become capable of anticipating a sound in their minds and generating it with the computer to produce more elaborate combinations leading to more complex musical patterns.

From this point on, students are aware of what they can do with this programmable instrument by setting a goal and carrying it out. There is an evident tendency toward perfecting the musical sentences and making them more expressive. The students are trying successfully to compose music they can dance to or sing, and to depict aurally some simple scenic actions and characters. The structure of the computer programs they create shows the development of musical intelligence and the ability of even quite young students to appropriate important concepts in their own way (Gargarian 1990; Bonta 1990).

Scientific research

Students at all grade levels and in every domain of science should have the opportunity to use and develop the ability to think and act in the ways associated with empirical inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. The general model of scientific research and the qualities required of a researcher have many things in common with the models and qualities described above as important for most social roles, far beyond the purely intellectual one.

Stages and types of research activity in school education are:

- formulating goals and research hypotheses;
- finding basic information, known experiments and results from the Internet and other sources;

- contacting experts, group discussions, carried on during face-to-face meetings and via telecommunication;
- overall planning of a project, correcting plans in progress;
- designing and constructing the investigation setting;
- running experiments in hands-on, automatic, and distant mode;
- observing results, measuring, and collecting data;
- analyzing and presenting data using mathematical models and means of visualization;
- discovering patterns, finding connections, making explanations and conclusions, verifying hypotheses and producing new ones; and
- conducting group discussions of results in classrooms and producing reports, presenting and publishing results via the Internet, screen, and text formats.

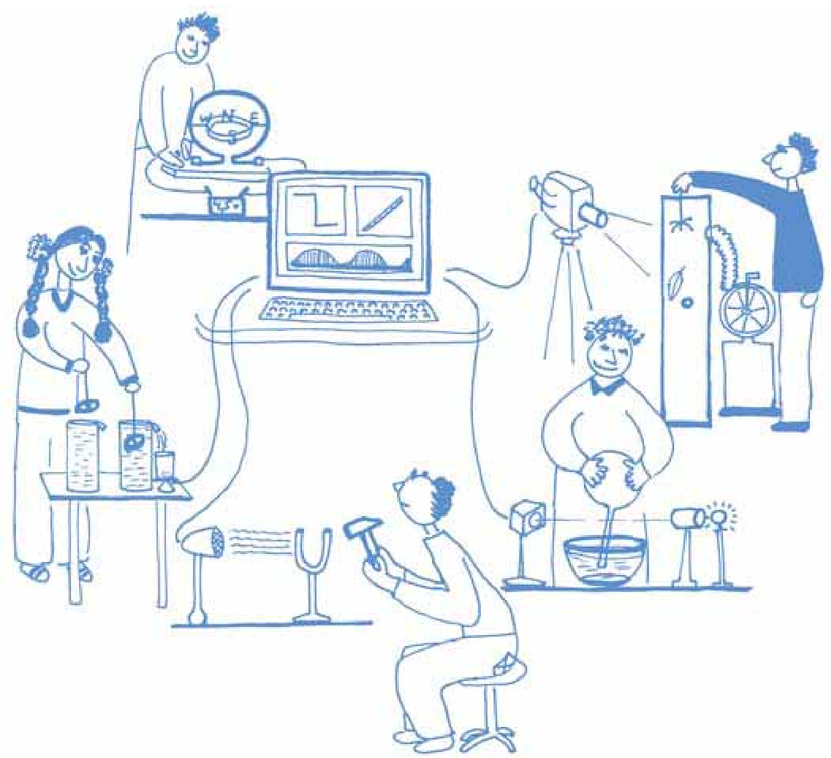
Based on the previous discussion, we can compile a list of hardware and software instruments to support these activities. Of course, special types of research may require special tools. These tools include:

- general office applications with text and graphics editing;
- lab equipment including computer-based testing and measuring devices; and
- tools for numerical and algebraic computations, spreadsheets, graphing, and statistical analysis.

Research in social sciences and humanities

Research in the social sciences and humanities has much in common with research in the natural sciences, as well as with artistic projects. Moreover, interesting educational results can be achieved in combination with different activities by, for instance, interviewing people for their opinion on a specific scientific fact or on the environmental consequences of an industrial process, or making pictures or drawings of local streets.

In this field, a research scenario might call for students to collect personally relevant information on their neighbourhoods, starting from their own files. It is conceivable that students start with the history of their family and expand it to a nation, and then to all humankind.



Organizing and presenting information, the creative and artistic recording of human impressions and transcribing interviews are some core elements of artistic and social science projects. In many cases, a project does not necessarily include every stage. For example, a design project need not actually be built, even in a physical model form, for the preparatory work to be rich and motivating for students. Sometimes the final result is a model on the computer screen; sometimes the important step is a discussion that leads to a new element in the project's future shape.

Providing support to the school and community

It is well known that among middle and high school students you can find high-class experts in ICT. The challenge is to cultivate the ever-expanding circle of such gurus and to use them productively for themselves, the school, and the local community.

A much more serious challenge is to prepare the school, the parent body, and the community for students' new roles. For example, in many cases it is worthwhile to exploit ICT belonging to the school after hours, when all formal lessons and informal school activities are over. A question then is whether we can trust students to keep order in the computer lab and support local citizens coming to use the computers.

All these decisions and changes should therefore include a strong organizational, social, and psychological component. For example, a special course for students on how to help *computer-reluctant* teachers and to empower and encourage them to use computers in the classroom can be an important component in transforming school practice.

Main advantages of ICT

In creating this new teaching and learning environment, ICT offer numerous advantages and provide opportunities for:

- facilitating learning for children who have different learning styles and abilities, including slow learners, the socially disadvantaged, the mentally and physically handicapped, the talented, and those living in remote rural areas;
- making learning more effective, involving more senses in a multimedia context and more connections in a hypermedia context; and
- providing a broader international context for approaching problems as well as being more sensitive response to local needs.

In summary, we believe that ICT enable teachers and students to construct rich multisensory, interactive environments with almost unlimited teaching and learning potential.

From the learning-teaching perspective, ICT should support:

- access to online resources that use a powerful combination of video, text and graphics, prepared by specialists in a centralized facility and delivered to individuals or groups by technology;
- provision for the teacher to teach a whole class or part of a class, assisted by technology as appropriate;
- provision for all students to learn the same way or to choose ways that suit their individual learning styles, assisted by technology as appropriate;

- access to individualized curriculum pathways, managed by technology;
- access to individualized diagnostic testing and assessment of progress, managed by technology;
- allowing students to move independently between learning areas as necessary, managed by technology;
- large screen video display (projector);
- individualized access to network resources including wireless networking; and
- continuity of access to network resources away from school.

The truly crucial question of how to evaluate learning in this new ICT-created-and-supported environment is too detailed to be described here even at the most superficial level. Interested readers can find a comprehensive survey of related issues in Heineke and Blasi (2001).