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NEW TOOLS FOR LEARNING

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The only thing I can say with a great deal of certainty... is that the evolution of human brain function has changed principally in response to the linkage between human beings and different tool systems. –Jerome Bruner

Abstract: In the last twenty-five years more has been learned about the human brain than in the past history of mankind. Through the use of new technologies such as PET and CAT scans and functional MRI's, it is now possible to see and learn much about the human brain while it is in the process of thinking. The research of neuroscientists, such as Marian Diamond, has demonstrated that the brain changes physiologically as a result of learning and experience —for better or worse — and that plasticity can continue throughout the lifespan. It appears that there are particular kinds of environments that are most conducive to the development of good mental equipment. They are positive, nurtiring, stimulating, and encourage action and interaction. Many of the most effective schools and training programs have created such high-challenge low-threat environments.

It is also very clear that intelligence is not a static structure, but an open, dynamic system that can continue to develop throughout life. This understanding is being utilized not only in school systems but in the workplace, where training programs show that even at the adult level people are able to develop their intelligence more fully. Corporations such as Motorola have implemented programs in which they are training their employees, managers, and executives to think, problem-solve and create more effectively using strategies developed by such educational innovators as Reuven Feurstein, J.P. Guilford, and Edward de Bono.

A most recent development is in the new kinds of technology that make it possible for people to take responsibility for their own learning as they access and process information through the internet, communicate with experts anywhere in the world, and use software that facilitates higher order thinking and problem-solving. Computers are in no way replacing teachers, but rather these new tools allow them to spend more time being facilitators, mentors, and guides. As a result, teachers and students are able more often to collaborate on creating new knowledge as well as mastering the basics.

As technology becomes more ubiquitous, there is growing recognition of the importance of the arts in humanizing the curriculum. "More high-tech, more need for high-touch" is becoming the by-word of many schools. They recognize that the arts are not only culturally important and civilizing influences, but they can facilitate the learning of almost any subject.

I believe that these four concepts — the plasticity of the brain, the modifiability of intelligence, the use of technology as a powerful new tool for learning, and the renaissance of the arts in education — have major implications specifically for educational systems and generally for the future of our world. In this time of rapid change, leading-edge educational systems are equipping people with the ability to learn, unlearn, and relearn continually. They are giving students meaningful opportunities to apply what they have learned in order to turn information into knowledge. And – of critical importance if any of this is to lead to a healthy future — they are helping students to learn to use knowledge responsibly, ethically, and with integrity. Furthermore, they are involving students in experiences that develop compassion and altruism in the process of their education. Our complex world urgently needs more people who have developed their fullest potential in mind, body, and spirit.

Tools That Form the Mind/Brain System

The human brain is the most complex and powerful technology on earth. It has become increasingly so over time largely as a result of need – and the tools we use to meet those needs. Thousands of years of walking (that freed the hands), making and using tools, and talking with other people catalyzed the physical growth and development of the human brain as well as great cognitive leaps of the mind. When people moved from pointing and grunting to using words, these verbal tools made it possible to communicate about things that were not in their immediate presence. They could talk about the past or the future; they could discuss abstractions; and they could tell stories that were much more complex than they could through the arts they had used such as painting, carving, dramatic, and dancing. It may be that story is one of the basic building blocks of intelligence with its roots in prehistoric times. Cognitive tools that facilitate story-making and story-telling and communicating may be among the most powerful ones in affecting the development of the human mind.

The development of additional symbol systems such as numbers, clocks, calendars, and musical notation created even more evolutionary possibilities for the brain/mind system. Another cognitive leap for humanity was facilitated when the printing press was invented. As growing numbers of people learned to read, they could learn about places they had never been from people they had never met. Their minds became increasingly able to deal with abstract thinking, and their ideas had new power as they were able to communicate with other people near and far.

In our own time, new tools in the form of electronic technology have been developed that may have even greater effects on human development. Not only can they facilitate the accessing of information on any conceivable subject from anywhere in the world, facilitate communication to people in nearly any country instantly, make possible the solving of complex problems, and be used to invent still more complex tools, but they are revolutionizing learning and cognition when used in ways that make full use of their power.

In no way do we suggest that the new technologies will rival or replace human interaction as an essential part of the learning process. Human learnings is by nature collaborative. Nor will these technologies replace a good teacher's empathy, nurture, and understanding and a good teacher's both conscious and intuitive ability to motivate, stimulate, and facilitate the learning of different student. These new tools will in fact free the teacher to be mentor, coach, and guide instead of a primary source of information and skills. It is good teachers who can best help students to understand and to turn information and skills into knowledge that they can apply in a number of contexts. The new research in

Distributed Cognition suggests that intelligence is not just in our heads. Part of it lies in our interaction with other people; part of it lies in the resources in our environment; and part of it lies in the tools we use. In order to discuss further the effects of new electronic technologies, let us consider some important information about the human brain, beginning with a simple analogy.

The Human Brain

A frequently used analogy is that of the human brain as computer. All too often in formal education the brain is limited to similar functions as primarily a storage/retrieval device. Unlike the computer, which is powered by electricity and programmed externally, the human brain is powered and transformed by multiple sources of energy, many of which are within. One source of energy is the blood supply which furnishes the brain with oxygen and glucose—so what we eat, drink, and breathe can energize or debilitate its function. Another source of energy is the sensory system which receives and processes visual, auditory, tactile, smell, and taste stimuli from the environment. The more aware we are the more alive we become. A third source of energy is an inner source, in the form of psychological drives such as interest, curiosity, motivation, and even passion. All these forms of energy are constantly working together to drive the human brain/mind system, and unlike the computer, with its hard drive, the human brain can continue to change, and develop, and improve as it is used in challenging ways.

The computer can store information without its affecting the inner workings of the machine, and that material can be accessed in the same form in which it went in. In many school systems, too often the human brain is required to store information and access it for use on standardized tests in exactly the same form in which it went in. This is a great way to test if information has been memorized (et least for a short period of time), but not sufficient to explore if the information can be applied in practical or even creative ways. Too often, it is not recognized that what the student takes in and how it is learned, can have a great effect on the brain/mind system. This computer–like approach to learning surely does not do justice to the complexity of the human mind at any perceived ability lever.

Dr. Marian Diamond, professor of Neuroanatomy at the University of California/Berkeley and recently director of the Lawrence Hall of Science, has been studying the human brain for several decades. Her work, along with that of numerous colleagues in the field, attests to the fact that the human brain can change physiologically as a result of learning and experience—for better or for worse. She points out that the brain is capable of making new neural connections (that we use to remember, think, problem-solve, and create) throughout life as long

as people are in environments that are positive, nurturing, stimulating, and that require activity and interactivity.

Not only is the brain capable of physiological transformation, but it is itself a transformer. It is in this capacity that it moves far beyond any other kind of technology. The human mind can transform abstract ideas into concrete reality, reality into abstract ideas, or one reality into another. For example, the human mind may think about thinking and transform that process into a statue of "The Thinker" as Rodin did. Or the human mind may take in the experiences of a lifetime and transform them into histories, tragedies, and comedies as Shakespeare did. Or the human mind can view an exhibit of paintings and transform them into music as Moussorgsky did when he composed "Pictures at an Exhibition". It can transform knowledge of science and technology into a new treatment for illness or transporting people to the moon. It can even create a kind of artificial intelligence from knowledge about the human brain/mind system!

Human Intelligence

Just as the human brain has been proved to have enormous plasticity, so apparently is human intelligence modifiable. The work of Dr. Reuven Feuerstein, Israeli psychologist and director of the Center for the Development of Learning Potential in Israel, demonstrates that intelligence is not a static structure but an open, dynamic system that can continue to develop throughout life. The strategies he has developed to teach the process of intelligence are now being used with remarkable success throughout the world with people of all ability levels from the profoundly retarded to the highly gifted, at all ages from infants to the elderly, and in a variety of settings from jungles to classrooms to board rooms. This system may soon appear in software form that will facilitate its use with people of all ages and ability levels.

J.P. Guilford's "Structure of Intellect" model, developed further by Drs. Robert and Mary Meeker, is also proving conclusively that there are more effective ways to identify and assess a greater range of intellectual abilities, and that there are now strategies to improve them. Key Technologies has translated the SOI model into a software program called "LearnSmart". Clearly I.Q. scores do not give a true picture of human intelligence, and it is now essential to change belief systems about what is possible for human beings to overcome, build on, and achieve.

Renee Fuller, psychologist who specializes in research on human intelligence, developed some years ago a highly successful, multisensory reading program for bright but dyslexic young children. The world she thought she knew as a professional psychologist came apart when she found that this program could

also teach retarded individuals with assessed I.Q's down to 20 to read with comprehension. The only people who did not learn were those with uncontrollable seizures that disrupted the sequence of their thinking so that they could neither understand nor retell stories. This finding led her to consider "story" as one of the basic building blocks of learning and intelligence. She went on the write an important little book called In Search of the I.Q. Correlation, in which she discusses the fact that she has not been able to find any correlation between assessed IQ and what people are able to learn. (Her program has not yet been translated into software.)

The educational implications of these findings about the human brain and intelligence are enormous. It is for this reason that some school systems are at last moving forward to implement programs which make it possible for all students to learn successfully. The same is true for training programs in large corporations. For example Motorola is testing both the Feuerstein and Guilford model in its training programs throughout the world. Feuerstein's strategies are being implemented in most of the major corporations in France, and are now moving through the European Economic Community.

Individual Differences

It would be an easier task if educational and training systems could apply the same strategies to help all students to learn successfully; however, the population of most countries is becoming increasingly diverse and people from different cultural, social, economic, and educational backgrounds have very different ways of learning, thinking, and behaving. It is essential to take these differences into account. Clearly, it is extremely difficult, especially in large classrooms, to individualize an educational program for each student, although multimedia technology and interactive computer programs are becoming more available and can be used some of the time for this purpose. It is possible, however, for teachers and instructors to become more aware of their own ways of learning in order to avoid teaching primarily in that way. Then they may expand their array of teaching strategies, so that at least part of the time their students have opportunities to learn through their strengths and learning preferences, and the rest of the time they have opportunities to stretch and grow as they use other methods. Equipping all teachers with a rich variety of strategies is one essential key to successful learning for all, and it surely makes learning much more interesting. Matthew Lippman once said, "When everyone thinks alike, no one thinks much".

There is a continually growing array of ways to assess individual differences and accompanying recommendations for meeting the learning needs of all

students. Following are some that have been found especially useful and are already influencing the development of software programs for use at all age levels and with many different subjects.

Perceptual differences are among the easiest to identify either by a number of readily available assessment devices or by direct observation. It is not difficult to identify the students who learn best by only listening. They are a small minority, although a large part of instruction is offered orally, and this method increases as students progress through school and higher education. A a result these students are usually successful learners. We can also identify those students who rely on accompanying visual materials in the form of illustrations, charts, diagrams, videos, and other graphics, And then there are those who must hold ideas in their hands in order to understand and learn. Cuisinaire rods, models, constructions, creative drama, and other physical activities and manipulatives are examples of successful for them. Many students who rely on kinesthetic learning experiences are understandably in special education and remedial classes, since these ways of learning are not available to them in many clasrooms. Prisons and juvenile detention centers are also full of people whose learning needs—often visual/spatial and kinesthetic—have not been met in classrooms where much of the instruction is offered abstractly.

Another kind of individual difference lies in "world view". There are those who look at one tree after another and come to the conclusion that they are seening a forest. Others see the whole forest before they pay attention to the individual trees. Herman Within calls these learners field independent or field dependent (or field sensitive). Field independent learners are more detail-oriented, less dependent on others, more analytical and sequential in their thinking; whereas, field sensitive learners tend to grasp ideas as a whole, are more affected by the emotional climate of the learning situation. It appears that field independent learners learn well in either situation, but the field dependent learner finds it very difficult to learn in contexts oriented to the field independent learner. Teachers who wish to reach all students will do well to offer "field sensitive instruction" in which the teacher is perceived as a "warm demander". This kind of instruction begins with an overview or global approach, establishes a warm relationship with students, works with a humanized curriculum, creates a highly supportive environment focusing on students' needs and feelings, ties learning into living, and encourages group achievement. Multimedia technology offers an important tool to present highly motivating and colorful overviews, and computer programs can offer positive feedback and support as students progress in their learning. They allow students to access information either in a linear, sequential way or more randomly, and they are invaluable tools for learning projects in which groups of students work collaboratively.

Multiple Intelligences

One of the most recent theories dealing with individual differences is The Theory of Multiple Intelligences, developed by Dr. Howard Gardner, Professor of Education and Psychology and co-director of Project Zero at Harvard University. He suggests that our culture and schools that reflect our culture teach, test, reinforce, and reward primarily two kinds of intelligence, i.e., verbal/linguistic and logical/mathematical. These are of course the foundation of the basic skills and important to functioning effectively in the world. He believes, however, that there are at least six other kinds of intelligence that are equally important. They are visual/spatial, bodily/kinesthetic, musical, naturalist, interpersonal, and intrapersonal intelligences. Altogether this constellation provides a broader view and a much more comprehensive way of describing human intelligence. These intelligences are tools for thinking, communicating, learning, and problem-solving, and they are languages that most people can speak, cutting through individual differences in ability, culture, and educational background. Gardner notes that "the ways in which intelligences combine and blend are as varied as the faces and the personalities of individuals".

As multimedia technology becomes more available to more students, we see how it can help teachers to provide both the important interactive and supportive environments that Diamond describes, as well as how it can be used to exercise and develop multiple intelligences. These tools are also useful in individualizing instruction, thereby meeting the needs of a growing diversity of students.

Electronic Technologies and Learning

As we consider different ways of learning and different ways of accommodating diverse learners, we may question whether the new electronic technologies really improve learning. The United States Advisory Council on the National Information Infrastructure has been asking this question nationwide, and following are some results of their investigation:

- A 1995 review of more than 130 recent academic studies found that using technology to support instruction improved student outcomes in language arts, math, social studies, and science. A congressionally mandated review of 47 comparisons of multimedia instruction with more conventional approaches to instruction found time savings of 30 percent.
- A review of New York City's Computer Pilot Program, which focused on remedial and low-achieving students, showed gains of 80 percent for reading and 90 percent for math when computers were used to assist in the learning process.
- A comparison of peer tutoring, adult tutoring, reducing class size, increasing the length of the school day, and computer-based instruction found computer-

based instruction to be the least expensive instructional approach for raising mathematical scores by a given amount.

- A 1993 survey of studies of the effectiveness of technology found that "courses for which computer-based networks were used increased students and student-teacher interaction, increased student-teacher interaction with lower-performing students, and did not decrease the traditional forms of communications used".
- Research on the costs of instruction delivered via distance learning, videotape, teleconferencing, and computer software indicates that savings are often achieved with no loss of effectiveness. Distance learning vastly broadens the learning environment, often providing teaching resources simply not available before. Technology-based methods have a positive impact on learner motivation and frequently save instructional time. Savings in training time produce benefits both by reducing training costs and by shortening the time required to become and remain productive in the workplace.
- A landmark study on the use of technology for children with disabilities showed that "almost three-quarters of school-age children were able to remain in a classroom, and 45 percent were able to reduce school-related services" when computer-assisted learning techniques were employed.

New Tools Open New Doors

The content of learning has always been based on where and how students access information. The more sophisticated the medium, the more complex the information that can be communicated. Today's students need some types of information to be available in formats that are more easily updated than the standard book format. A typical textbook takes years to produce and be adopted. We have only to consider the changes taking place in nations comprising the former Soviet Union during the past five years to see how all existing textbooks in history and geography must be inaccurate at best. Changes in the fields of science and technology are even more rapid and texts become obsolete even faster. Books will not disappear from classrooms. Students will continue to read anthologies, biographies, and historical documents, as well as novels and short stories from the printed page. Librarians and teachers are turning to new tools for learning, reporting that as more students use new technologies to get information, use of libraries and standard texts actually increases. Students in fact tend to read more, possibly because they are introduced to new ideas "surfing" the internet, and because new resources have expanded the average library's reference capabilities. Student reports become more complex and far-ranging as a result.

New Tools and the Future of Education

These kinds of projects utilize technology as powerful tools to bring together the real world and the world of classroom learning. And it is already bringing about a transformation in how students are educated. Technology now makes It possible for students to:

- break down barriers, Including physical, cognitive, geographical, cultural, and economic.
- learn in ways that accommodate their own learning styles and kinds of intelligence
- learn basic skills and all subjects more effectively
- access and manage information
- practice and improve communication skills
- communicate with peers and experts anywhere
- move beyond memorization to deeper understanding
- practice working both independently and collaboratively
- assume greater responsibility as a learner
- explore and expand intelligence
- continue learning throughout life.

In his Testimony to the U.S. Congress, House of Representatives In October, 1995, Dr. Chris Dede, professor of Education at George Mason University said: "Many people are still reeling from the first impact of high performance computing and communications: shifting from the challenge of not getting enough information to the new challenge of surviving too much information. In a few years, the core skill for American workplaces will not be foraging for data, but filtering and synthesizing a plethora of incoming information. The new type of literacy students must master will require diving into a sea of information, immersing oneself In data to harvest patterns of knowledge just as fish extract oxygen from water via their gills. Understanding how to structure learning experiences to make such immersion possible will be the core of the new rhetoric. Expanding traditional definitions of literacy and rhetoric into immersion-centered experiences of interacting with information will be central in schools preparing K-12 students for full participating in the 21st century society".

Such new kinds of skills are now essential in order to function effectively, intelligently, and productively in an increasingly complex world filled with challenges no one can fully anticipate. To prepare students for such a world demands that educational systems make the best possible use of all the knowledge, wisdom, and technologies currently available.