COMPUTER BASED LEARNING: INSIGHTS FROM LEARNING THEORIES AND INFORMATION TECHNOLOGY

Mokhtar Amami  
Department of Business Administration  
Royal Military College of Canada  
Kingston, Canada

Jack Brimberg  
School of Business Administration  
University of Prince Edward Island  
Charlottetown, Canada

Abstract. Information technology is revolutionizing the educational system, but where this revolution is taking us is not fully understood. This article reviews three fundamental components that shape human learning: knowledge accumulation, psychological development, and imagination, and their interrelationships. It also reviews the capabilities of information technology as an enabler for transforming learning processes. Further, the article attempts to integrate the capabilities of information technologies to the varieties of views on curriculum design that have evolved from the learning theories. This analysis leads to a conceptual model for computer-based learning that integrates six set of variables: learning tools, integrated technologies, conditions of learning, learning goals, learning processes, and learning outcomes. For curriculum designers, the model provides a framework for transforming learning processes an improving learning outcomes using computer-based learning.

Keywords: Information technology, computer-based learning, learning theories, learning technologies, electronic education, curriculum design.
1. INTRODUCTION

In an information society and a knowledge economy, business leaders, academia, and governments are more and more preoccupied by the role of education and training. Business enterprises are looking for knowledge workers who are skillful, creative, autonomous and trustworthy. Although the curriculum of an education system cannot be designed to fit the immediate needs of business enterprises, schools and universities have to redesign their curriculum to fit the new technological and cultural development that societies are witnessing all over the world. The present educational system cannot support the new cultural and technological change that is sweeping globally all societies.

The crisis of the current education system has its roots, not in the insufficient size of the budget allocated to it, but in its heart: the curriculum. The dominant design principles of the current system are based on four conflicting views. The first view of curriculum design follows the Durkheimian socialization curriculum design principles, which aim at initiating the young into the norms, values, and conventions of the adult society, and shaping the thinking process to fit a type of understanding that governs human behavior (Durkheim, 1956). Therefore, the learning process is based on creating the adequate mental preparation to learn the rules, norms, and values that ensure both societal stability and development. The second view of curriculum design follows the Skinner (stimulus-response theory) (Skinner, 1969, 1974) and Plato-Kant (rationalism) curriculum design principles (Kant, 1952). The design intends to provide knowledge accumulation and logic that help individuals to construct a rational understanding of the world in order to apprehend reality through valuable and sufficient experience. The use of the mind as a dynamic interpreter of reality, combined with the accumulation of knowledge through experiences, ensures that the learner’s thinking will conform to what is real and true. The learning process of grasping this knowledge follows a path that emphasizes reason, experiences, and psychological linkages between the known and the unknown. The third view of curriculum design follows Piaget’s psychological development design principles (Piaget, 1954, 1967a). The design considers human beings as complex cognitive systems of interdependent cognitive processes. The design is based on how information is collected, processed, and integrated into theoretical frameworks. It borrows heavily from the biological sciences, philosophy, and mathematics. From the biological sciences, Piaget describes the adaptive framework required to interpret, organize, and synthesize information, and from philosophy and mathematics, he describes the hierarchical nature of cognitive structures (Piaget, 1967b). According to Piaget, curriculum design should aim “to learn to learn, to learn to develop, and to learn to continue to develop after leaving school” (Piaget, 1973, p. 30). Finally, the fourth view of curriculum design follows the Rousseauian design principles (Rousseau, 1969a). Curriculum design must integrate imagination as a source of freedom and as a capacity that enlarges the bounds of possibilities. Imagination is a “dynamic process” of acquiring knowledge and a vehicle for bridging psychological development and knowledge accumulation (Egan, 1992).

The natural wisdom of this categorization of curriculum design of education is that schools and universities can balance the curriculum by integrating the values of all four views. The fundamental problem with the integration of these views is that education is not only aims and programs (e.g., writing, reading, scientific knowledge accumulation, psychological skills, etc.); education is how each individual constructs a framework of understanding from a complex web of knowledge. Education is also how each individual resolves the conflicting views about responsibilities, obligations, and rights, and about society’s goals and governance mechanisms.

The dilemma with education is that every individual claims to be an expert with a precise understanding of of what should be the content of education. This makes it very difficult to balance the variety of views and to prompt a debate on education and curriculum design. The end result is that the standard curriculum has been largely designed taking one dominant view and rarely two; and, to
make matters even worse, this unidimensional view is not likely to change for some time. For example, a curriculum that has been conceived in terms of knowledge accumulation and rationalism is not wrong, but cannot deliver the needed elements to build a holistic view. Rather, it can only deliver partial elements of a more complex view of the world. What is particularly wrong, in a context in which education has been largely conceived in terms of knowledge accumulation, is to exploit the immense capabilities of information technology (IT) in education using just one view. If we ignore all the potential benefits of IT, we may end up automating a curriculum that is incapable of delivering the dynamic effect of meaning-constructing that energizes individuals, increases their capacity, and expands their bounds. Consequently, there is more to this issue than just bringing more IT to education.

The increased focus on the role of IT in education is taking place in an environment characterised by unprecedented speed, increasing complexity, spreading electronic networks, rapid knowledge creation and accumulation, and rapid technology innovation and diffusion. More importantly, IT is forging the creation and development of relationships among people all over the world and ultimate linkages among a variety of systems. The current curriculum does not adequately support this new environment, where more complex frameworks of understanding are required. As a result, curriculum design has become much more demanding, especially in universities. The new age requires:

- Smarter, faster, and diverse ways of learning that create, capture, synthesize, share, access, and process knowledge to build complex frameworks of understanding.
- Incorporation of a dynamic driver that complements knowledge accumulation and psychological development for holistic learning that supports individuals and organizations (whether enterprises or educational institutions) to cope with turbulent and more complex environments.
- Taking advantage of IT for developing electronic channels and open networks for increasing rich communication and collaboration among students and educational institutions.
- Using IT to expand student bounds and enrich collaboration and problem identification.
- More flexible curriculum-based IT that helps individuals take constantly shifting “reality” and environments and translate them into a coherent and stable view of the world.

Given all these stringent requirements, how can the university curriculum be transformed and IT-enabled to be an effective agent? That is the main challenge this paper addresses.

2. IT AND CURRICULUM DESIGN

Despite optimistic predictions (McLuhan, 1965; Kay, 1991) and the growing interest in the potential of computer-based learning (CBL) (Isakowitz, Stohr & Balasubramanian, 1995; Nielsen, 1990; Thuring, Hannemann & Haake, 1995; Alavi, 1994; Anonymous, 1995), little has been done to adequately develop design principles for CBL. Further, little is done to define and characterize new curricula computer-based systems. The literature on the application of IT to teaching and learning portrays a narrow vision of how to use IT to enhance learning. Part of the literature advocates how IT may provide better-quality learning (Norman, 1991; Norman and Spohrer, 1996; Benjamin, 1994; Kay, 1991, Skillinorn, 1997), while another part of the literature puts more emphasis on the virtue of the technology to support distance education (Jensen, 1993; Capell, 1995; Ma, Lee, Du, and McCahill, 1998; Hardman, Bulkerman and Rossum, 1994; Cordero, Harris and Hsieh, 1996; Dwyer, Barbieri and Doerr, 1995; Prevelakis, 1998).

The two dominant arguments that surface when examining the literature on the application
of IT for education-on-demand (EoD) or computer-based learning (CBL) are the following. First, because traditional classroom settings due to various constraints, such as time, cost, distance, physical disabilities, and family obligations (holding a job, caring for children at home), limit student attendance, universities have become increasingly interested in delivering EoD systems. These systems provide distance learning opportunities that can enhance learning, and improve the ability of universities to stay ahead of funding reductions. Learning enhancement can be achieved through the integration of different media such as video, audio, music, text, images, and animation to satisfy a variety of educational objectives. It can also be achieved through the expanding possibilities of open electronic networks that support the learner to find, filter, and file an ever-increasing body of knowledge. Second, because funding allocated to universities, and to educational systems in general, is decreasing rapidly, universities are seizing EoD as a way to attract more students and compete with each other geographically and globally.

The following extract summarizes very well the current ambiguous thinking on the application of IT for EoD:

"Journey with me to a time when there is a powerful computer—a workstation—on the desk of every learner and every teacher and trainer. These workstations are connected to a network, which enables them to reach any source of information, anywhere, and at any time. They are also portable and can be used wherever there is a network connection, for example a telephone or a suitable radio signals.

Those workstations are provided to learners at no initial cost. Each learner will have a unique identity and will pay for the capability only as the workstation is used. In this context we can see the similarities with other utilities such as electricity, gas, and water.... This approach removes at a stroke, the capital barrier that has prevented 85 per cent of the population from using and benefiting from the new technologies.

Now imagine that every learner can, at his or her own choice of time and place, access a world of multimedia material, which is stored electronically and locally. Immediately the learner is unlocked from the shackles of fixed and rigid schedules, from physical limitations and most importantly, is released into an information world, which reacts to his or her own pace of learning. A window to knowledge is open.

Now at last the learner can revisit a solution not completely understood, view again how a problem was solved, call a colleague for a discussion, request advice from a teacher (to whom I want to refer from now on as an educator), or reach for help from a library. This is as true for the engineer who is retraining and the adult who is retraining, as it is for the child learning at primary school.

Individualised learning supported by educators and trainers, who are a keystroke away, represents a transformation from the way in which our education and training are currently delivered and organised. It will create an opportunity for the individual to "do education" rather than have it done to them; it will reform and strengthen the relationship with the educator and give more emphasis to coaching, counselling and participation. It will transform teaching to learning" (Benjamin, 1994).

However, the application of IT to education is not neutral. The application of IT for EoD should be paralleled, or, better, preceded, by a transformation in the current curriculum, which is conceived mainly in terms of knowledge accumulation. Two models can be portrayed to highlight the application of IT for EoD (see Figure 1). Model 1 shows that the application of IT for EoD provides the same end result. The major consequence of the EoD is an education at lower cost delivered to a larger number of students. It may improve the accumulation of knowledge and provide a better quality of learning, but not a better quality of understanding of the environment and reality.

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1 In this article we use interchangeably EoD and CBL. This equivalency may be misleading since The Open University had been offering EoD before the introduction of computers into education. However, the introduction of computers transformed education by making it only a click away. Due to the ease and speed of CBL, we advocate that the equivalency is justified.
However, Model 2 shows the application of IT as an enabler that supports a new curriculum. In this model the application aims at capitalizing on the potentialities of IT to deliver an “educated mind” (Egan, 1997) that not only receives a quality learning, but, more importantly, a mind that can fit complexity, environmental turbulence, and fugitive reality and truth. In others words, Model 2 reengineers education (Alavi, Wheeler, and Valacich, 1995).

IT plays a critical role in the EoD, but it is one that has not been fully understood or utilized. The primary objective of the current application of IT seems to be to deliver courses at lower cost and higher speed. The main result could be an automated curriculum with a reduced number of teachers and an education system characterized by higher productivity. The major drawback of this view is the use of IT as a solution to increase an education system’s efficiency without a comprehensive coupling of IT potentials with the theories of learning and understanding. Applying IT for the EoD requires a change in the curriculum that recognizes the critical role of IT in education. The redesign principles of the new curriculum should identify the potentialities of the technology, such as responsiveness, developing natural learning, encouraging learners to form creative hypotheses, etc.

**Model 1:**

![Model 1 Diagram]

**Model 2:**

![Model 2 Diagram]

**Figure 1: Stream-Line thinking and understanding or improving the knowledge Accumulation**

The question is how to design a new curriculum that prepares educated students. What are the reference disciplines that should be used as a basis for developing this new curriculum? What is an “educated student”? What is “rich understanding”? The answers to all these fundamental questions are beyond the scope of this article. Therefore, the article will be limited, first, to investigating how to integrate learning theories with the capabilities of IT, and second, to developing a conceptual model for computer-based learning in order to deliver EoD that provides rich understanding. We draw on the work of information systems researchers, communication researchers, learning theory researchers, and educational researchers. The conceptual model integrates six sets of variables: learning tools, integrated technologies, conditions of learning, learning goals, learning processes, and learning outcomes. Several insights are derived from the model that can be valuable to the curriculum designer.

Our main contention is that fundamental reference disciplines should be used as a basis for developing a theory of computer-based learning or EoD. This study advocates that research done in learning theories and information technology provides valuable insights for the EoD designer.

The relevance of learning theories is a natural consequence of the focus on such basic premises as goals formation, creativity, understanding context building, knowledge construction and accumulation, etc. (Schunk & Osgood, 1992; Piaget, 1954, 1967b).

The relevance of information technology is a natural consequence of the focus on its capability (capacity, quality, and cost) and functionality (storage, processing, and communication)
dimensions (Huber, 1990; Bakos, 1985). These dimensions of information technology allow the use of multimedia, video-based hypermedia, electronic textbooks and other electronic tools to support and foster learning.

3. LEARNING THEORIES AS A SUPPORT FOR CBL

Technology plays a substantial role in designing a curriculum. The use of technology for knowledge transfer and accumulation, and for testing (e.g., multiple choice tests) reflects, intentionally or unintentionally, a kind of learning theory. Learning theory is a vast domain; however, compressed into its basic three components, one can draw several insights that can be used to develop and design a consistent and relevant university curriculum that exploits the opportunities of CBL. Figure 2 shows the three basic sources of learning (Egan, 1997; Leidner & Jarvenpaa, 1995). Let us highlight briefly the characteristics and the assumptions that underlie each component.

3.1 The Traditional Theory of Learning: Knowledge Accumulation and Rationalism

Knowledge accumulation and rationalism are the basic pillars of the current curriculum. The basic contention of the current curriculum is that knowledge accumulation and its organization are critical for successful problem solving in complex and real environments (Chase & Simon, 1973; Simon & Simon, 1978; DiSessa, 1983). There are different types of knowledge: factual, semantic, schematic, and strategic (Norman, 1997). The current curriculum seems to be biased toward factual and semantic knowledge with a secondary emphasis on the last two types of knowledge. Thus current curriculum puts too much emphasis on declarative knowledge that is related to basic statements about the subject. This type of knowledge seems important to individuals in the sense that it helps to decide what procedures to use to solve problems. It also emphasizes semantic knowledge or the "knowledge about concepts and relationships that give sense and meaning to the facts" (Norman, 1997). Let us examine the basic sources of this learning theory.

The traditional theory of learning that we call knowledge accumulation and rationalism is a combination of two views: 1) empiricism; and, 2) rationalism. The empiricist theory, known also the objectivist theory or the behaviourist theory, assumes that reality exists independently of the learner. According to this theory, an object exists whether or not it is perceived. If a learner cannot detect an object or a phenomenon, it is simply because he/she did not accumulate enough experiences and therefore knowledge, and may not have the right instrument. Knowledge acquisition can be obtained through an accumulation of experiences judged as the only reliable source of knowledge. The theory is based on Skinner's stimulus-response theory. For Skinner learning can be defined as a change in behavior that can be detected by observing an organism. In order to understand learning, then, one must understand the causes of the change in behavior which can be shaped by positive or negative reinforcement (Skinner, 1969, 1987). Furthermore empiricism builds on the assumption that complex ideas are constructed from simpler elementary ones that become more conceptual and integrated as experiences accumulate.
Figure 2: Components of learning

The primary goal of teaching is to use the expert as a transfer channel of knowledge to the learner. The mission of the expert is to train the learner to engage in experiences in order to detect and understand reality. Moreover, the role of the expert is to lead the learner to a state where he/she can only trust valid experiences as a method to gain insights, generalize, and derive laws that have predictive and explanatory power. The teacher can use Gagné's instructional theory (Gagné, 1985a) to transfer knowledge.

The rationalist view is known also as idealism, interpretivism, or Platonism. According to this view, suggested first by Plato and later developed by Kant, the primary source of knowledge is reason. The learner uses the mind to construct reality according to an innate-perceptual model. This view assumes that the mind is not a passive organism that accepts all sense data as reality, but is rather a dynamic organism that actively organizes the data to build an interpretive framework. In terms of teaching and research, the rationalist view assumes that the role of the teacher is to transfer knowledge by pressing the learner to use the mind to understand the constructed reality. The role of the teacher is to communicate enough information through lectures that are organized in a way that fits the learner’s pace. The ultimate goal is to guide the learner toward a kind of understanding where the mind is able to search for the truth by setting working hypotheses and focusing on differences.

Empiricism is a fundamental element of the traditional university curriculum, particularly in North America. For example, comparing teaching and research between European universities (mainland) and North American universities, one can characterize the teaching and research in Europe as more rationalist oriented and North America as more empiricist oriented. In the latter case, teaching is more oriented toward experiences and cases, and research is more data-gathering (experiences) and analysis-oriented. Furthermore, the typical lecture starts with an example and evolves to more complex and conceptual thinking.

3.2 Psychological Development

The second component, which we call psychological development, and which represents one of the two dominant theories, assumes that knowledge acquisition is a process of continuous self-construction. This view hypothesizes that knowledge is not external to the individual, but rather is the result of invention and reinvention as the individual develops and interacts with the world. Because a large part of psychological development and knowledge acquisition is constructed by individuals engaging in actions that pursue goals, the literature refers to the psychological
development, or Piaget theory of learning, as a constructivist theory of learning. Piaget is known as a fierce opponent of empiricism and not a firm believer in the view that knowledge is entirely innate. Piaget adopted a view consistent with rationalism that suggests part of knowledge is innate and part is acquired. Piaget labelled this view interactionism.

As Piaget’s theory of psychological development is fundamental to understanding the constructivist view, the article will devote more space to it. Cognitive support, behavioural support, and performance linkages are the three major elements that are systematically studied in the literature of psychological development. Cognitive support is a portion of psychological development that explains how humans process information. Precisely, learning models that relate to cognitive support study the process by which a human acquires, interprets, and adapts to stimuli and, consequently, learns. A variety of studies (Solso, 1973; Gagné, 1985b; Anderson, 1982; Lindsay & Norman, 1977) seem to support that a human develops his own cognitive frameworks and then uses them to manipulate stimuli, and thus learns how to make decisions and to behave. Behaviour support examines the linkage between stimulus and response and, therefore, of incentives and disincentives in behavior. Behavioral learning focuses on factors such as timing and nature to reinforce certain behavior patterns. Performance linkage focuses on how individuals identify the causes of their failures and successes. This linkage of performance to root causes is fundamental to provide a holistic view of learning support.

Although, these three areas of research - cognitive, behavioural, performance- are overlapping, we will focus only on cognitive learning because of its appropriateness for understanding how humans process information and build mental frames. Both aspects are fundamental to developing curricula intended to enhance learning and education.

Cognitive learning and information processing theories abound. They are, however, similar. They describe how information is collected, processed, and integrated into mental frameworks (Wittrock, 1986). Information is collected through observation or reading. Processing is performed through induction; then, propositions are generated and behaviour is obtained. When new information is collected, it is adapted and the mind and its cognitive structures continue to develop and learn.

Two fundamental concepts are particularly relevant to curriculum design: adaptability (learning) and frame development. Adaptation refers to two different processes: assimilation and accommodation. Assimilation consists of gathering new information and incorporating it into existing cognitive frames. This process leads individuals to update their information and build new assumptions that fit their cognitive framework. Accommodation is a process that leads to rearranging, redefining, and developing an emerging cognitive framework capable of handling and interpreting new or equivocal information.

Frame development describes the evolution of the cognitive framework. We will narrow our investigation to two major aspects of frame development - schema and data grouping - due to their relevancy to hypermedia and curriculum design. Schema is a sequence of activities that enable an individual to interact with the environment. A young child, a lawyer, a design engineer all learn through sequential activities that, once incorporated and aggregated, will form a complex means-ends sequence behavior. As experiences accumulate and intellect develops, the schema becomes less a set of interrelated instances and more like abstract ideas that make no reference to physical representation. Data grouping refers to the process of scanning and collecting data and then operating grouping based on context and logical processing. The grouping allows individuals to gain new insights and discover new intra-group and inter-groups relationships. As discovery progresses, complex structures evolve by creating information hierarchies (Flavell, 1963).

The last important aspect of cognitive theory is conservation or cognitive operation, which is defined as the capability of a human to distinguish between changes that affect fundamental properties of an object and changes that alter some dimensions while keeping the object invariant.
In order to achieve conservation, people must perform three basic operations: 1) classification (the capability to classify things along two dimensions: similarities and differences); 2) reversibility (the capability to transform objects and return them to their initial state); and, 3) equilibrium (the capability to understand that a change in one dimension is balanced out by a change in another dimension).

The constructivist view hypothesises that individuals are better learners when they are active, self-directing, cognitive entrepreneurs who develop their minds through a great many spontaneously generated information-processing activities (Flavell, 1984). The learner, however, must have some abilities in carrying out activities such as controlling his own pace, searching and asking questions, researching answers, investigating and interacting with peers and the expert or the teacher. The instructor serves as a counselor to provide tools and help when necessary. The instructor can direct and reorient the learner, who remains the main person responsible for constructing his/her own reality (Jonassen, 1993). The instructional goals that are consistent with the constructivist view are reasoning, critical thinking, problem solving, retention and understanding, cognitive flexibility, and mindful reflection. The conditions of learning that are consistent with these goals are complex and rich environments that incorporate real activity (Spiro, Feltovich, Jacobson and Coulson, 1991), social negotiation (collaboration and sharing cultural values) (Bruner, 1986), nurturance reflexivity (the learner is aware of his/her own role in the knowledge construction) (Cunningham, 1987), and student-centered instruction (the learner is actively involved in determining what his/her own learning needs are and how to satisfy them) (Perkins 1991).

Among the conditions of learning, social negotiation that can be categorized under the banner of collaborative or socio-cultural learning may constitute an interesting field for computer-based learning. Part of the social negotiation model is a derivative model of the constructivist theory. Culture and cultural development are at the heart of social negotiation. Culture, which is intrinsic to humans, can be defined as a set of attributes and products of human societies which are transmissible by means other than biological heredity. Cultural development is best understood if we examine its dynamics in terms of the psychological development that occurs when the human mind grasps such basic features of the world as space, time, nature, past, present, fears, greed, desires, beliefs, uncertainty, and so forth. According to Piaget's theory of psychological development, cognitive growth of humans follows a trajectory of cultural development to understand the world and develop an increasingly sophisticated cognition to master constant innovation and ensure cultural development. Because cultural development is due to some aspects of the human psyche, Piaget's theory of psychological development can frame the fundamentals of socio-cultural learning.

In contrast to the constructivist view and mainly the Piaget view, where learning occurs when individuals interact with objects, the socio-cultural view assumes that learning occurs when individuals interact with other individuals through discussion, information sharing, and, particularly, by understanding the cultural perspective. Vygotsky (1962, 1978) and Bruner (1962) believed that individual thinking and development cannot be understood if the social and cultural context and development are not understood. Vygotsky rejected Piaget's equilibration principle with regard to understanding cultural development and hence intellectual thinking. For Vygotsky, culture and historical perspective cannot be dissociated. Historical perspective refers to how the development of thinking is an internalization of the tools of one's culture. Further, as the culture emerges, develops, and changes, the thinking follows suit. In contrast to Piaget's view, which focuses on the organism and context as the unit of analysis, the Vygotsky-Bruner view is centered on their interaction. In contrast to the objectivist view, which assumes that development is learning, and to the Piaget view that development is a precondition for learning, Vygotsky's view assumes that the interaction between them enriches thinking. How do we build an instructional method that
is consistent with these views? This is a real challenge for teachers and experts.

3.3 Imagination

Finally, the third component that we call imagination is the Rousseauian view. This view follows the "Réveries du Promeneur Solitaire" of Jean Jacques Rousseau (Rousseau, 1969a, 1969b), which stresses imagination as a source of freedom and as a capacity that enlarges the bounds of possibilities. Imagination stimulates desires and hopes, but it also stimulates fears that can, in turn, stimulate invention and discovery, whether for human good or for atrocities. Dominated particularly by rationalism and empiricism and partially by psychological development thinking, the current curriculum excludes the imagination as a "dynamic process" (Egan, 1992) of acquiring knowledge and as a vehicle of bridging among these varieties of learning views. Imagination is that part of the human psyche that leads to forecasting tomorrow's needs and to examining things that are actually considered taboo, prohibited, or impossible to do. If Jules Verne relied only on rational and cognitive faculties, he would never have written his marvelous futuristic novels. If artists, scientists, and technologists relied only on their accumulated knowledge and psychological skills, it does not seem that very much would ever have been discovered and developed. It is not easy to explain the complex linkages among imagination, knowledge accumulation, and psychological development and how these linkages affect learning.

As stressed earlier, the objectivist view assumes that learning is a dissemination of knowledge that can be maximized through abstract representations of reality and when the learner is in isolated settings. Reality and controlled experiences show also that learning can occur through collaboration (the collaboration model of learning), and that learning occurs best when the learner is able to interpret knowledge and use it in a way that fits the historical socio-cultural development.

Learning cannot occur in a vacuum. To discover and innovate and exploit innovation we need a process of knowledge dissemination. To increase our knowledge and enhance our learning, we need to accumulate the knowledge of others. We can cite at least three basic reasons that justify knowledge dissemination: 1) it is a very unfortunate, long, and frustrating path for humans to rediscover what other humans have already accomplished; 2) major discoveries and innovations are accomplished by exceptional humans in very particular (even unique) contexts; and, 3) knowledge dissemination can lead individuals to confront the thinking of a variety of others and to evolve from egocentricist to sociocentrist thinking.

The efficiency of discoveries, innovation, and production systems are not independent of human psyche. Psychological skill, motivation, and so on, form a fundamental part of the psyche that explains learning and the level of sophistication in thinking. In particular, the Piagetian view that knowledge acquisition occurs through appropriate assimilation and accommodation that results in an equilibrated cognitive structure is relevant. Therefore knowledge is invented through learning. However, if learning creates knowledge, the acquisition of learning is also a pre-condition for a higher level of learning.

So why was imagination excluded from the educational curriculum? How does imagination enhance knowledge dissemination? How in turn does knowledge dissemination expand imagination? How is psychological development linked to imagination? There is no established and cumulative research that can substantiate answers to all these questions. However, if we look back at history and examine the socio-cultural trajectory, we can understand the exclusion of imagination from the educational curriculum. From the ancient Greeks to the end of the 17th century, imagination was a suspicious concept. First Plato considered imagination as untrustworthy because he believed it to spring from an "inferior" part of the mind. In contrast, he believed that reason formed the upper parts of the mind, which alone could discover truth and the world reality. Second, imagination was distrusted because imagination might lead humans to attempt to foresee the future.
One might have expected that the early Enlightenment would have carried new thinking about imagination. Unfortunately, Francis Bacon (an early scientist) considered it as a way to entertain the mind when the mind’s serious work was already accomplished, and the rational Descartes treated it as a source of confusion that might blur the mind and logical analysis. The only philosophers who considered imagination positively were David Hume and Immanuel Kant. Hume characterized imagination as a converter of sense impressions into ideas. Kant suggested that what we perceive and know is already predetermined by imagination. Unfortunately these views did not attract followers. The major reason can be explained by the Hume’s and Kant’s conceptions of the world. Because Hume was an empiricist and Kant a rationalist, both later reduced the role of imagination. Because this “faculty of magic” could not be explained, they both reduced the importance they had attributed to it earlier.

What then is imagination? Imagination is an essential ingredient in creativity that plays key roles in judgement and choice. These two dimensions (which are time and space independent) require the ability to imagine the relative likelihood of different outcomes. In making judgements and choices, individuals use imagination to create things to produce effectiveness that did not exist previously. Bruner (1962) highlights three types of effectiveness: 1) predictive (e.g., the law of falling bodies); 2) formal (e.g., groupings in mathematics, logic, music, and so on); and, 3) metaphoric (e.g., connecting domains of experience). Johnson (1972) distinguishes three stages for creative activity: 1) preparation (knowledge acquisition through courses, reading, and discussion); 2) production (ideas generation); and, 3) judgement (evaluation of ideas prior to selection).

Knowledge accumulation plays an important role during the first stage. The linkages between knowledge accumulation and imagination are critical for preparation. Although chance plays some role in creative thinking, in the preparation stage, knowledge accumulation is critical to seize the opportunity. It is extraordinarily difficult for an individual who never accumulated knowledge in economics to look at economic problems from a new perspective such as Keynes did during the thirties. It is likewise extraordinarily difficult for an individual who never accumulated knowledge in physics to come up with great creative theories such as Einstein did.

Psychological skills and motivation are important factors to aid the “production” stage or ideas generation. In this stage a constructive framework of the mind, a relaxed attitude, independence of mind, and high motivation plays crucial roles. During this stage, psychological development is essential for individuals to have free and unconstrained thinking.

The third stage that involves judgement and prediction of a variety of outcomes requires a mind that systematically examines solutions and that has evolved high motivation and persistence, a risk-taker behavior, and, finally, “good taste”.

In summary, imagination and creativity are intertwined. They play crucial meaning in judgement and choice. Imagination is also intertwined with the objectivist view because knowledge accumulation is essential to preparation (first stage of creative activity), and to the constructivist view because ideas generation (second stage of creative activity) requires unconstrained thinking. The three stages of creativity require both convergent and divergent ways of thinking. In contrast to the collaborative view, which supports collaboration to foster knowledge, the art of creativity thinking seems to occur best when individuals are freed from work habits, social norms, and strict respect of the community rules. How to balance collaboration and freedom of choice is an important question for the teacher, the project manager, the political leader, and so on. From the curriculum design view, imagination should be explicitly recognized as a faculty that does not belong just in the realm of magic proper only to genius, but as a faculty that allows us to make free choices. All that is needed from the “common” ordinary individual at all levels of society and all levels of thinking is the willingness to invest the mental effort necessary to achieve it, or, as Einstein put it, “99 per cent hard work.”
### 3.4 Summary

Table 1 displays a summary of the various learning theories in terms of basic assumptions, educational goals, methods of instruction, and the principal advocates. Theories of learning focus on and describe the process of learning. Rationalism builds on the assumption that reason is the source of knowledge. In contrast, objectivism builds on the assumption that experience is the source of knowledge, knowledge accumulation is learning, and knowledge exists independently of the learner. Constructivism, which has recently taken a strong hold in many areas of education today, is not one theory but a multitude of derivative theories or better learning models. The basic assumption is that learners construct knowledge. Further, knowledge construction does not necessarily bear any correspondence to the world as it really is. One important derivative learning model is the socio-cultural model. It asserts that learning is subjective and one needs to internalize the cultural “tools” and understand the historical cultural development in order to understand the context of knowledge transfer. Finally, the imagination approach of learning supports the concept

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<td>• World reality is constructed by the mind.</td>
<td>• Transfer of knowledge</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Objectivism or Behaviorist</strong></td>
<td>• Experience is the source of knowledge</td>
<td>• Knowledge accumulation</td>
<td>• Instructor designs and delivers knowledge in a controlled environment</td>
<td>B. F. Skinner</td>
</tr>
<tr>
<td></td>
<td>• Knowledge accumulation is learning</td>
<td>• Transfer of knowledge</td>
<td>• Positive and negative reinforcement is used to shape the behavior</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Knowledge exists independently of learners</td>
<td>• Retention and recall of knowledge</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Constructivism</strong></td>
<td>• Construction of knowledge through the development of abstract concepts</td>
<td>• Knowledge is constructed by learners</td>
<td>• Instructor serves as the creative mediator of knowledge construction and as a discussant in assigning meaning to events</td>
<td>Jean Piaget</td>
</tr>
<tr>
<td></td>
<td>• Social interaction and negotiation</td>
<td>• Knowledge construction does not necessarily bear any correspondence to the world as it really is</td>
<td>• Explore social/cultural context</td>
<td></td>
</tr>
<tr>
<td><strong>Imagination</strong></td>
<td>• Imagination is the driving force to creativity and knowledge creation</td>
<td>• Promote creativity</td>
<td>• Instructor develops the capacity of the learner to be creative in order to enrich rational thinking.</td>
<td>Jean Jacques Rousseau</td>
</tr>
<tr>
<td></td>
<td>• Imagination structures perception</td>
<td>• Promote freedom of choice</td>
<td>• Instructor develops the capacity of judgement.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Imagination allows freedom of choice</td>
<td>• Extend the learner bounds</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 1: Summary of learning theories*
that imagination is the driving force to creativity and knowledge creation and structures perception and allows freedom of choice. There is considerable tension among these various learning theories and approaches. No particular theory or approach can entirely suit an instructor’s views on education. These different views highlight the complexity of human thinking and development. Instructors should be aware of this complexity and try to avoid a unidimensional learning model. This means that instructors, depending on the conditions of learning, should integrate more than one theory in their instructional methods. Information technology capability can help the instructor deliver courses that fit human imagination and complexity.

4. INFORMATION TECHNOLOGY AS A SUPPORT FOR CBL

The relevance of learning theory is a natural consequence of the focus on education and training taken by CBL. Chute, Hancock, and Balthazar (1991), Kay (1991), Norman (1991), Alavi (1994), Skillicorn (1997) and Alessi and Trollip (1991) discuss the role CBL must take in supporting education and collaborative learning. Isakowitz, Stohr and Balasubramanian (1995) and Thuring, Hammemann and Haake (1995) present methodologies for developing hypertext/hypermedia navigational structures that support learning. There are a variety of available technologies that can support education on demand (EoD). All computer-based delivery systems include at least one of the following characteristics: 1) digital sound; 2) images; 3) text; 4) graphics; 5) video; and 6) music.

4.1 Hypertext Systems

A hypertext system is a distributed database of chunks of information, cross-referenced by various types of links, accessible by a large number of individuals, and supporting a variety of navigational, manipulative, communicational, and operational activities (Nelson, 1987). A user can browse, manipulate, annotate, and retrieve information. The hypertext system thus allows a user to extend intellect and to communicate and cooperate with others over a range of distances. The potential of hypertext systems, if they become widespread, may ultimately bring “all books onto everyone’s desk and all information just a mouse-click away” (Nelson, 1987). Hypertext systems have already gained some ground in electronic publishing, such as electronic encyclopedia systems and electronic collections of maps. The main potential of hypertext systems is the help that they may provide to delinearize human thinking. McLuhan (1965) has pointed out that linear text has narrowed our view of the world. This delinearization may help individuals to better communicate ideas and tackle complex issues, and to become aware of the web of supporting and conflicting arguments and of the large volume of data and information that are easily accessible. Hypertext, then, can extend our memory and expand our bounds of rationality. Hypertext systems can be used as an instructional system that supports constructivism and imagination.

4.2 Multimedia/Hypermedia Family

Multimedia and hypermedia families integrate all the above characteristics to form an instructional system that supports the general learning factors such as interactivity, adaptability, situated learning, and retention (Capell, 1995; Jewell, 1994; Ambrose, 1991; Dede, 1992). There are numerous and often ambiguous definitions of multimedia and hypermedia. A simple and very straightforward definition of multimedia could be a system that mixes voice, text and graphics (Barfield, 1993). One can also define multimedia as “any computer application that employs a video disk or images from CD-ROM, uses high-quality sound, or uses high-quality video images on a
screen" (Preece, 1994). Further, we can expand these definitions to hypermedia to include communication and networks. "The name hypermedia has been applied to networks of nodes (also called articles, documents, files, cards, pages, frames, screens) containing information (in text, graphics, video, sound, and so on) that are connected by links (also called cross-references, citations)" (Shneiderman, 1992a, p.404).

The development of information technology functionality (storage, processing, communication) and capability (capacity, quality, cost) (Bakos, 1985) allows the rapid and widespread use of pictures, diagrams, animation and movies. The development of these functionality and capability dimensions of IT will increase the value and the applicability of hypertext/multimedia/hypermedia systems (HmH) in education. It is our contention that whatever the view of the educator (objectivist or constructivist), HmH will deeply influence how humans acquire, create, and disseminate knowledge. It will also enrich communication and relationships.

To substantiate how HmH affects learning and enriches communication and relationships, let us first examine how it may complete the counterpart of our most important sensory organ (the eye), and how it can enhance understanding and elevate the level of abstraction of the learner. Maurer and Carlson (1991) and Maurer (1992) observed that, while our second most important sensory organ, the ear, has the mouth as an active counterpart, our first sensory organ, the eye, has no such complementary organ. Further, while a human can generate speech and music (using the vocal chords), he is unable to display — in real time— concrete or abstract images. A human can store real images or images that no one has ever experienced, but he lacks the capability to externalize them. Humans have tended to translate these images into words and words into writing, or to draw pictures. To alleviate this deficiency (images-generating organ), humans have used cameras to display real (and not experienced) images. However, the use of cameras as picture-generating equipment limits the level of abstraction and leaves no room for imagination and creativity. Recently, the use of computer graphics and visualization is starting to compensate for the missing "images-generating organ." Because half of the human neocortex is devoted to visual information processing, it seems there is an unconscious desire to feed our eyes with visual information. Schools and universities have to capitalize on this desire by redesigning the curriculum, and adopting the computer as a learning tool. By redesigning the curriculum, they may even find that students will devote more time to learning instead of watching movies and television.

The HmH systems will improve the externalization of mental imagery. The rapid progress in software tools and interface-mechanisms will eventually make it possible for humans to display images in real-time as they generate speeches. Still underestimated by a majority of educators and universities these new capabilities of information technology will revolutionize product and process development, marketing, cyber leisure, learning, communication, and, most importantly, the kind of understanding. Television is an obvious example to illustrate how a passive and rudimentary visualization medium has shaped the framework of understanding of people all over the world. The rapid progress in visualization tools such as process and data visualization, 3D modeling, animation, and so on, will have an extraordinary impact on communication, relationships, and thinking.

Let us focus on how HmH systems impact communication and thinking. Schank & Osgood (1992) portrayed two basic models of natural communication. First, the standard view of natural communication consists of decoding words into ideas (on the input side) and mapping ideas into words (on the output side). Second, the Artificial Intelligence model of communication consists of four separate modules: language generators, language parsers, language inferencers, and knowledge bases. All the knowledge is kept in the knowledge base. Anything new that the language parsers can digest is inputted into the knowledge base. To figure out new thought, both the inferencer and the knowledge base are used. To say something, the language generator extracts from the knowledge base the desired information and translates this into words.

Schank & Osgood (1992) observed that both models are unsatisfactory. The first model
assumes that no prior knowledge is necessary in order to communicate and understand, and no linkages are needed between learning and knowledge. However, people need to build a common knowledge to understand each other. The relevance of the new knowledge is relative to the relationships to the prior knowledge. Consequently, it seems that communication is intimately linked to knowledge and knowledge building requires prior knowledge. HmH systems offer a tremendous opportunity for the learner to build the prior knowledge necessary to communicate and, hence, to accumulate further knowledge. The second model is not adequate either because of the separation among the four modules. It is extraordinarily difficult, for example, to learn a foreign language if the language parser is separate from the knowledge base.

Hypertext and fully digitized multimedia systems are merging into hypermedia systems (this is why we call this HmH systems), providing easy access to large databases and knowledge bases, integrated superhighways and cooperative infrastructures, and a number of software tools and advanced man-machine interfaces that not only extend our memory and processing capacity, but also the communication capability. Schank & Osgood (1992) hypothesize that “if communication is organized around memory and memory is full of stories, then hearing stories about others’ experiences and telling stories about one’s own experience is the basis of human communication.” As experiences accumulate and the context changes, peoples’ stories change, the content of communication changes, relationships change, and consequently the knowledge and the kind of understandings change. Using HmH systems, the learner can map his/her own stories onto the instructor/colleague/collaborator’s stories to ensure communication and understanding, and thus, the knowledge construction (the constructivist view), or knowledge creation (the imagination view), or knowledge accumulation (the objectivist view).

The artificial intelligence community explored case-based reasoning, indexing (internalizing a concept or story requires an attachment in memory), and story-based communication as a bases for building artificial communication. If story-telling is fundamental, then computers can help tell stories and mimic human conversational behavior. Further, computers must have some built in methods to figure out the story to tell next.

“The modern AI view is that technology can extend direct natural human communication beyond time and location constraints using machine mediation. That is the real meaning of artificial communication. Video players can put us in touch with the world’s great story tellers without their being there. Intelligent interfaces can have buttons that let users have some control of the process of learning from stories, so it feels like a real two-way interaction (Jona et al., 1991). A new hypermedia technology called ASK Systems lets users browse through stories and get answers to questions in a conversational way even with experts from history (Ferguson et al., 1992). The key is indexing (Schank & Osgood, 1992)”.

Although the HmH technology is not mature and not yet able to support all of the goals and desired outcomes of an educational system, its potential is tremendous. It is only a matter of time before the superhighways have sufficient bandwidth, reliability, and interfaces to support a challenging EoD. The new HmH systems will extend the frontiers of learning beyond the classroom, the campus, the city, and the nation to create what we might call a global educational system. One can hypothesize that the tremendous impact on cultural development and the kinds of understanding that will develop will be enough to propel us into a new era of permanent prosperity.

4.3 WWW Based Learning

Internet is the prime example of a hypermedia which is linking millions of users around the world to provide opportunities for distance education (Dwyer, Barbieri and Doerr, 1995). The Internet will be a major source of learning in the future (Butler, 1995; Santa Vicca, 1994. Internet-
based learning allows users to create their own instructional paths by searching informative contents through hierarchical and referential links (Bilotta, Fiorito, Iovane and Pantano, 1995). Internet-based learning capabilities support a distance-education environment that: 1) fosters cooperative learning and participation by bringing together a community of learners into a virtual classroom; 2) allows students to develop their own schedule and pace of learning; 3) allows for a fast access to the latest version of a document (e.g., a new publication); and 4) ensures the fit between the teacher’s philosophy and style and the user’s educational needs. The key features of Internet are: 1) global reach; 2) capability to link; 3) shared ownership; 4) flexible and diverse platforms; 5) public resources and 6) cost advantages. Universities can capitalize on the use of the Internet to increase the capacity of learning and improve the quality of learning. They will have to design the academic curriculum based on collaboration with other universities using Internet support. Actually, Internet use as an interactive teaching method is experimental. However, as a new medium, Internet may offer interesting opportunities (Harris, 1993). E-mail, discussion forums (Usenet news), file transfer, navigation tools, WWW, etc. can be attractive tools for improving learning, fostering collaboration, and reducing the cost of academic programs.

The use of the Internet, however, raises major issues that range from technical considerations to socio-cultural aspects (Ibrahim and Franklin, 1995). Technical considerations cover information technology equipment, networking protocols, user interface and line bandwidth. For example, www based textbooks allow for flexible, immediate, interactive, low cost distant learning. However, the usefulness of electronic textbooks depends heavily on their design. Quality design includes considerations such as user friendliness, organization of information, annotation, information sharing, and copyright. Bandwidth is another technical consideration that limits the effectiveness of using the Internet, for example in medical education where high-resolution images are required (Schneipf, Du, Ritenour and Fahrman, 1995). Although ATM (Asynchronous transfer mode) technology can provide high-speed networks, and thus, the capacity to distribute images and other materials in real time, there is a long way to go before ATM technology becomes a standard for future broadband integrated services digital network applications. From the technological perspective, the Internet provides promising capabilities that are of particular interest for education [see Ibrahim and Franklin (1995) who developed two complementary pedagogical strategies that can exploit these capabilities].

Socio-cultural aspects cover relationships among students and norms and values which develop during the learning process. Some argue that Internet-based learning reinforces a "cocooning" attributed to a growing insulation from the outside world. This behavior of keeping the outside world out may encourage people to ask for magic within. The lack of interaction with the real world may increase the tendency to fantasize and to be incapable of distinguishing reality from imagination. Furthermore, the lack of face-to-face communications may translate into a “loose culture”, and consequently, a society that has no bonds, no past and no future.

Many other technologies that involve one or more media elements may be used either as stand alone or as an integrated instructional system. Annex A cites and describes briefly seven types of instructional technologies.

4.4 Summary

Table 2 matches learning technologies and learning theories.
Table 2: Correspondence between learning theories and learning technologies

<table>
<thead>
<tr>
<th>Learning Theories</th>
<th>Learning Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructivism</td>
<td>• Hypertext, Hypermedia, Multimedia, Groupware, Virtual Reality, Simulation Models, Internet.</td>
</tr>
<tr>
<td>Imagination</td>
<td>• Virtual Reality, Simulation Models, Hypertext, Hypermedia, Multimedia, Internet.</td>
</tr>
</tbody>
</table>

In summary, the rapid emergence of HmH and related applications (e.g.; Internet, virtual reality, etc.), the sharp decrease in cost of multimedia-capable PCs, the constant development of larger bandwidth, and the constant improvement in the machine-man interface will remove traditional barriers and allow individuals to:

- Capture high-quality lectures anywhere and anytime, thereby eliminating spatial and time constraints;
- Choose among a variety of learning styles (e.g., learn by doing, symbolic thinking, etc.);
- Filter information through the combination of WWW sources and course material;
- Increase interaction with teachers and peers;
- Improve interaction by running simulations, exploring new related fields, and reviewing prior knowledge;
- Have more control over their schedule and consequently better knowledge review and knowledge acquisition;
- Be more imaginative and creative and consequently combine reason and imagination to design and implement the educational curriculum;
- Acquire a good education at a reasonable cost.

5. A CONCEPTUAL MODEL OF COMPUTER-BASED LEARNING

The previous section reviewed, analysed, and surfaced up a variety of views and concepts from learning theory and the relation of information technology to this theory. The following conceptual model attempts to integrate these varieties of views, concepts, models, methods, and so on. Educational institutions and researchers are in need of a conceptual model that can frame curriculum redesign and learning technologies adoption and implementation. Any educational institution that is tempted to offer a system of EoD should ask and carefully document the following four fundamental questions:

1. What are the technological resources that can be developed to support an education-on-demand?
2. What are the learning goals and the conditions of learning of the educational curriculum?
3. What are the learning processes that map technological resources, learning goals, and conditions of learning into learning outcomes?
4. What are the relevant learning outcomes that fit an educated mind?
Learning Technologies
1. Learning Tools
   - Newsgroups
   - Electronic books
   - On-line multimedia
   - Computer-Based Training
   - Hypertext
   - Electronic cases
   - Electronic mail
   - Databases
   - 4th GL
   - Instructor Console
2. Integrated Technologies
   - Hypermedia
   - Microworlds
   - Intelligent tutoring
   - Groupware
   - Internet
   - Expert systems
   - Electronic Performance Support
   - Virtual reality
   - Simulation models

Learning Processes
- Control of pace
- Content
- Learning style
- Participation
- Intactivity or engagement
- Adaptability
- Retention
- Attention
- Context or learning situation
- Information retrieving and filtering

Learning Goals
- Reasoning/arguing
- Knowledge transfer and acquisition, etc.

Conditions of Learning
- Rich learning environment
- Social interaction
- Assisted learning ownership
- Awareness

Learning Outcomes (Educated Mind)
- Motivation/Attitudes
- Cognitive strategies
- Quality learning
- Self learning
- Levels of learning
- Levels of thinking
- Performance
- Participation
- “Sticky” knowledge
- Judgement/creativity

Figure 3: Conceptual Model of Computer-based Learning
Our conceptual model is built upon four inter-related building blocks which are highlighted in Figure 3 in three distinct domains: 1) domain D1 describes two blocks or groups of variables; 2) domain D2 describes the processes; and 3) domain D3 describes the outcomes. Due to the relative newness of the CBL research area and the complexities of human learning, the linkages between the three domains are not well established. Further, the studies devoted to these linkages are dispersed across disciplines and across methodologies. The relevancy of EoD to learners and educational institutions in general makes it important to unify the research in the CBL field.

The conceptual model highlights relationships among variables by the red arrows that link the two left boxes to the box in the middle and the arrow linking the process box to the outcome box. The primary objective of the intermediary variables, referred to hereafter as learning processes, is to map the four groups of variables (learning tools, goals, conditions of learning, and integrated technologies) into the outcomes. Without these intermediary variables, one cannot understand the source of variation in the outcomes across different experiments.

Before examining the six sets of variables displayed in the boxes of the conceptual model, let us focus briefly on the dashed arrows that link the far-left variables to the outcome variables and on the double pointed arrow hanging over the boxes. The dashed arrows represent the use of information technology tools (e.g.; electronic books, databases, etc.) and integrated technologies (e.g.; hypermedia, expert systems, etc.) for automating rather than transforming learning. The dashed arrows point, thus, to the vision to automate learning without impacting the core processes of learning. Although some aspects of the objectivist theory are prone to automation, we argue that IT should be used as an enabler of the new curriculum that will build new kinds of understanding. Because IT can have a strong impact on collaborative learning, constructing knowledge, and creative thinking, the new curriculum design should aim at transforming the core learning processes in order to realize all relevant learning outcomes (i.e., an educated mind).

Learning theories and the assumptions underlying them are the most important determinants of learning goals selection, instructional tools and technology choice, and outcomes design. Despite the variety of views, learning theorists from philosophers to psychologists do share two fundamental definitional assumptions: 1) learning refers to a persisting change in human performance; and 2) learning requires experiences. An educational institution that seeks to redesign its curriculum around information technology has to deliberately create conditions that fit these two fundamental definitional assumptions.

5.1 Learning Tools

Learning tools refer to hardware and software tools that can be used by teachers and learners to deliver presentations (e.g., instructor console), communicate (e.g., e-mail), retrieve and manipulate information (e.g., 4GL), and make graphical displays for enhanced presentation (Benbasat and Dexter; 1985). The primary aim of learning tools is to automate portions of teaching and increase the productivity of the educational system (Harris, Murden and Webster, 1993; Winter and Harrington; 1994; Souder, 1993). For example the instructor console makes the presentation more vivid and less time consuming. Because the course is better organized and the instructor is more prepared, more materials can be covered and more time for informal discussion is freed. The e-mail system can increase the communication between instructor and learners. Portions of the course can be covered outside of class thereby increasing the work-load through the use of e-mail. Students who are not able to comprehend the parts covered out of class would then communicate with the instructor to ask for clarification or more references. However, it is unclear whether the learning outside the class is similar in quality to that obtained through the traditional lecture. Using learning tools, teachers, experts, and trainers are able to increase course content, control the pace of learning...
and consequently make the learner acquire more knowledge. The use of information technology in education tends to reproduce a similar pattern to that of business organizations. From the 1950s to 1990s, the role of information systems went from automating the accounting system to general support of the organization to promoting survival and prosperity of the organization. The use of information technology went from stand-alone applications and islands of technology to integrated applications and a wired economy. The transition from one era to another was long and painful due to process reconceptualisations and organization restructuring. The use of learning tools by many educational institutions and instructors tends to follow the same pattern—using IT to automate and increase classroom productivity. The tools tend to be used as stand-alone applications or systems, and often, the learning processes are ignored. The significance of these learning tools is presently based on the assumption that learners learn more effectively and efficiently when the right tool is supplied to them. This stimulus–response–feedback model fits the objectivist view.

5.2 Integrated Technologies

The integrated technologies cover hypermedia, Internet, groupware, virtual reality, and so on. These technologies require an advanced level of integration and thinking. Fortunately most of these technologies have the capabilities to support a variety of learning processes such as interactivity, retention, adaptability, learning context, learning style, and others. However, the major problem facing learners, teachers, and educational institutions is how to fit these technologies into the curriculum. The adoption, implementation, and use of the new technologies require a redesign of the curriculum and new thinking—for example, how do we use virtual reality in the old curriculum built on the assumption of knowledge accumulation. Virtual reality (VR) provides three major capabilities: experiential education, constructivism, and sociocultural learning. Papert (1980) and Bruner (1962) showed the fundamental role of experiences in the learning process. Virtual reality involves participants in different learning experiences. Interaction in a VR environment involves different human dimensions: cognitive factors, affective domains, and the psychomotor. VR involves students in a constructive environment where they can create, manipulate, update, and edit digital information. In this environment they can build their own categories of thought about the world and construct their own knowledge. In the traditional curriculum, students are spectators in the classroom, acquiring facts rather than vivid knowledge useful for building a kind of understanding. Because of an inherent lack of experiences, they often do not value the information given to them. Vygotsky (1978) defended the idea that “human learning presupposes a specific social nature and social process.” Networked VR provides shared environments that foster collaboration among distant participants who bring their own views, values, understanding, and culture. The same reasoning may be extrapolated to hypermedia, simulation technologies, and groupware. It is very difficult to take advantage of these technologies if we leave the old curriculum unchanged. The new technologies require a new level of thinking to achieve an educated mind. It is not realistic to resolve the problems of today by using the same level of thinking that created the problems to begin with (Einstein). We only see the tip of the iceberg if the new technologies are used only as a means to develop a more elegant delivery system that conveys the same message.

5.3 Learning Goals

Learning goals and conditions of learning are derived from existing learning theories. Because learning goals vary across theories, across curriculums, and from general to specific, it is not easy to identify a set of goals that is congruent with conditions of learning, learning processes, and most important congruent with learning outcomes. The literature is full of confusion between learning goals and learning outcomes. Learning goals are not very meaningful to learners. They are
useful for educational institutions and teachers in order to establish a congruence between goals, methods of teaching and yardsticks to measure the result (Dick & Reiser, 1989; Gagné, Briggs and Wagner, 1992). For example, one of the goals of a computer science curriculum might be to have students “really understand computer architecture.” Obviously, across curricula, teachers, computer firms, and students, the “level” of understanding may vary. If we go one step further, one can identify many outcomes relative to the level of learning, thinking, and creativity that result from teaching a computer architecture course. It is extraordinarily difficult to measure precisely the level of understanding acquired by a student. That is why testing and examinations, although inescapable requirements in a curriculum, are not an exact science. Why are there many outcomes related to an assigned goal? There are no really clear answers. However, it is certain that outcomes will vary as a result of conditions of learning and learning processes.

5.4 Conditions of Learning

Conditions of learning have attracted researchers and theorists with diverse views. For Gagne’ (1985b), who adopted information processing theory, the conditions of learning include both internal events (e.g., prior encoded information) and external events (e.g., methods to facilitate encoding). He established five learning outcomes (verbal information, intellectual skills, cognitive strategies, attitudes, and motor skills) and their critical learning conditions. For example, cognitive strategies require: 1) describing the strategy; 2) providing a variety of occasions for practice using the strategy; and 3) providing informative feedback as to the creativity or originality of the strategy or outcome. Constructivist researchers from different perspectives (psychological development, socioculturalism, and collaboration) have put forward four basic conditions of learning:

- Rich learning environment
- Social interaction
- Assisted learning ownership
- Awareness

Rich learning environment refers to complexity. According to most constructivist theorists, learning occurs best when students are confronted with complex problems that may be encountered in real life. Oversimplifying concepts, models, and problem-solving will not expose the learner’s misconceptions. Complex learning will lead learners to construct models, confront them to reality, and discover inconsistencies and inadequacies. From the constructivist view, the use of simulation models and virtual reality allows learners to construct complex models and test their validity. From the cognitive information processing view, virtual reality can help students to process information, and therefore, learn by making abstract concepts or complex products more concrete.

Vygotsky (1978) stated that “higher mental processes in humans develop through social interaction.” Cunningham (1992) supported that interaction in a social setting is fundamental for grasping other views. According to the socioculturalism and collaboration views, learning and thinking occur when the learner interacts with others learners. Social interaction and working in groups enable better insights and quality learning. The use of groupware, Internet and hypermedia allows students to interact with people outside the classroom, and therefore, to understand perspectives other than their own.

Perkins (1991) stated that student ownership of learning is essential for autonomous thinking and learning. Knowledge that is acquired from the teacher, textbook writer, and video producer is not likely to “stick” because it is not owned and thus not motivating. Motivation, which is a relevant outcome, is increased if the learner has “ownership” and control over or personal engagement in the experience. Consequently, learners who can construct their own ideas directly from experience,
without mediation, are more likely to evolve to a higher level of thinking. Electronic performance support systems provide in-context learning in a realistic setting. The interactive capability of the system makes it easy for the learner to learn. Because the system is readily accessible, any information or skills that are forgotten can be generated and mastered on demand.

Finally, students' awareness of their own role in the learning process helps them to think and reflect on the knowledge they are acquiring and the assumptions underlying this knowledge (Papert, 1984). This attitude toward learning engages students and moves them to be more imaginative and free thinkers. Students can use simulation models to test their own ideas and confront them with reality. What is more, students can challenge assumptions and "The de facto Truth".

5.5 Learning Processes

Learning processes may be defined as a set of variables that when correctly identified and focused on will enhance learning outcomes. There are a variety of learning processes. The box in the middle of figure 3 highlights the most cited and researched processes. Let us focus on the role of some these.

"Learning style seems to play a major role in the learning processes (Yoon, 1994). The traditional curriculum privileges analytical learning styles, which emphasizes spoken and written language. This means that learners who are proficient in the relational styles, which emphasize visual and audio stimuli, are unfairly disadvantaged. Further, it is well documented that relational learners fail in school far more often than analytical learners do (Lee, 1986). Teachers and educational institutions have to redesign the curriculum by matching teaching styles and learning styles. There is some emerging evidence that academic achievement increases and more positive attitudes toward learning result when students are taught according to their learning styles. Virtual reality (VR) technology brings a sense of immersion and the inclusion in a virtual educational environment that may allow students an opportunity to interpret and encode their own perceptions of the world. Further, the multi-sensory capabilities provided by the VR technology enhance the relational styles and thus motivate and engage learners to learn.

Interactivity is being considered more and more as a fundamental requirement for high quality learning. As a learning process, interactivity enhances quality learning measured by: 1) time on task, 2) immediacy of feedback, and 3) learner engagement. Interactivity implies that students are engaged on working with other people in paired collaborations, team projects, and class presentations. This type of interactivity "can teach valuable skills that are now left to sports teams and after school clubs" (Shneiderman, 1992b). Engaging processes will motivate learners to explore new knowledge and be more creative to accommodate other views. The new rich environment created by HmH (hypertext-multimedia-hypermedia) technology, Internet, Groupware, and other integrated technologies increases student interest. Shneiderman (1992b) reported that "students in a graduate seminar on user interface design undertook the common task of reading research journal papers and critiquing them, but interest in the task increased when they were required to send their critiques to the authors by email. The discussions were deeper, the usual off-hand attacks were softer in tone, but sharper in insight. The replies and contact with leading professionals gave my students a sense of importance and maturity."

Adaptability is another learning process that can be an effective form of instruction (Anderson, 1982). Because the learning system can adapt to the learner, this form of tutoring can provide insights and explanations that fit the learner's needs in real time. Intelligent Tutoring Systems have a multimedia capability in addition to other features which provide neutral but deep insights about the learner's performance.

Attention and retention are internal learning processes that support gaining attention and enhancing retention and transfer, two of Gagné's nine events of instruction (Gagné and Driscoll,
Attention is a learning process that seems to play an important role in student learning. The availability of multi-sensor technology can help regain student attention and increase knowledge acquisition. Retention is another learning process that helps learners to combat knowledge decay. Because the time between lessons and real applications is often not simultaneous activities, the ability to recall weakens. Electronic Support systems provide students with adequate support when they are on-the-job or practicing.

Context or situated learning as a learning process furthers student thinking and learning. The situated learning, when effective, invites student participation in concept development, problem solving, and creative thinking. The most cited example of situated learning is the flight simulator, which is designed to immerse the learner in a context that is a close approximation of real flight. Information technology offers a variety of potential applications where the learner can experience a situation similar to real life.

5.6 Learning outcomes

Learning outcomes are often classified as being cognitive outcomes (Bloom and Krathwohl, 1956), affective outcomes (Krathwohl, Bloom and Masia, 1964), and psychomotor outcomes (Simpson, 1966). This taxonomy is based on Bloom’s notion that learned capabilities comprise three principal areas: cognitive, affective, and psychomotor. Gagné (1972) attempted to integrate the three areas and proposed a taxonomy of learning that comprises five distinct outcomes: verbal information, intellectual skills, cognitive strategies, attitudes, and motor skills. Although relevant, Gagné’s taxonomy reflects a unidimensional view, that is the cognitive information processing view. The far right box (figure 3) includes a variety of major categories of learning outcomes that correspond to a variety of views. A curriculum designer can select among the categories those learning outcomes that correspond to the view of the community. As clarified earlier, we believe that learning occurs best if the three components of learning are integrated (see figure 2).

Quality of learning refers to consistency from one class to another and from one school to another. One of the major advantages of a well-designed, interactive, computer based learning system is the absence of degradation across classes and schools. The curriculum designer does not have to focus on tightening the specifications of the educational system, rather he has to put more emphasis on designing a quality computer based learning. Because the new technology helps learners to “guide their own learning, thinking, acting, and feeling” (Flynn, 1992; Gagné, 1985a), the curriculum designer has to create the conditions for students to attain a “high level of thinking and learning”. It is not easy to define and characterize the notion of a “high level of thinking and learning”. But one can argue that it refers to thinking independently, imaginatively and creatively. Independence, imagination and creativity relate to several learning outcomes such as level of thinking and level of learning.

Properly planned and implemented, information technology will support quality learning and create a hedge against degradation across classes, schools, and teachers. Moreover, this new capability of information technology may increase the level of thinking and the level of learning.

Attitudes may be defined as a set of acquired internal states that influence the choice of an individual (Gagné, 1985b). Since the attitudes are affective in nature, they may reduce or increase the value of acquired knowledge. One may have great knowledge about teaching but be a poor teacher if the attitudes are to dictate power. A manager may have a large and extensive knowledge and experiences in managing an R&D laboratory, but kill creativity if the worldview that governs employee action is not consistent with the manager’s worldview. Krathwohl et al.’s taxonomy of affective outcomes refers to five categories: receiving, responding, valuing, organization, and characterization by value. Gagné’s definition of attitudes corresponds to the two first categories: receiving (willing to receive information) and responding (becoming involved). These two
categories are fundamental to attitude formation. A positive attitude toward learning requires that learners possess a set of related concepts and information pertaining to an attitude that will generate an action. The first category (receiving) is called the informational component of an attitude. The action generated following information reception constitutes the behavioral component of an attitude. The emotional component of an attitude refers to the feeling that accompanies the choice of action generated. Information technology can play a major role in shaping the informational component and to a lesser degree the behavioral component. The Internet is expanding at a very high rate, bringing more information closer to learners. For example, learners may use the Internet to obtain information on environmental issues. This may lead to an understanding of the various sources of pollution (informational component). Simulation modeling may then provide an approximation of a likely action that may affect the environment (e.g., building a dam to generate electricity) (behavioral component). Information technology can, therefore, shape some aspects of the prerequisite internal conditions for establishing attitudes. External conditions (e.g., attitude of parents, sports star etc.) may reinforce the attitudes.

Attitude and motivation are intertwined in a sense that attitude can act as a motivator for learners. However, motivation may be a transitory state that lasts only a short period of time. Attitude and motivation formation may be reinforced over time. This view is consistent with the objectivist learning theory and precisely with Skinner’s views.

The use of hypermedia, groupware, Internet, and so on, will have, a major impact on how knowledge is acquired, created and transmitted. These new technologies that are capable of shaping both the attitudes and processes of learning, will transform the instructor from a dictator to a new role as mediator. The likely outcome of the application of information technology in the learning domain will be to shift the control of the content and pace of learning into the hands of the student. The objectivist method of instruction within the domain of explicit knowledge will probably cede to the constructivist view of instruction where knowledge is created than transferred. The shift of control of the content and pace of learning into the hands of students will bring new challenges to the curriculum designer.

Cognitive strategies refer to the capabilities to monitor one’s attention and to develop a personal encoding scheme that makes the knowledge “stick”. Since learners guide their own learning, they tend to avoid problem-solving when the problem is defined by others. The new technology offers new ways for learners to express themselves by defining their own problems and developing new rules. These will encourage them to focus more on new problems rather than on problems with known solutions.

6. INSIGHTS FOR REDESIGNING A CURRICULUM AROUND COMPUTER-BASED LEARNING

Curriculum is the core of an education system. It defines a framework of understanding that the learner is expected to build and develop. In reviewing the literature on learning theories and IT, and developing the conceptual model of computer based learning (figure 3), several insights may be gained.

The curriculum designer must be aware of the fact that the role of IT is to support learning processes to produce better outcomes. IT should not determine the curriculum, rather it should facilitate learning conditions and support learning processes. The technology offers the opportunity to learners to experiment with new ways of doing things. In engineering, physics, medicine and marketing, for example, possibilities exist to do things that may contradict moral or religious values and challenge the judicial system (Russell, 1994). The new way of learning will transform the power relationship between the learner and the parent or instructor. How will the world that the
learner has created and is experiencing be controlled? How will the learner discriminate between fact and fallacy? Moral and immoral? How should the curriculum be redesigned to free learners to use their creative imagination, to shift the level of thinking, and to control the new world they are creating and experiencing? There is no easy and quick answer to these questions. However, the curriculum designer has to recognize the inescapable trade-off between the huge benefits of IT to learners, and also the risk that IT can create in “freeing” the imagination.

**Insight #1**

*There are two primary considerations in redesigning a curriculum around CBL: IT and learning theories. The IT selection should leverage the learning processes to enable optimum learning outcomes and allow the curriculum designer to trade-off IT benefits and risks.*

The aim of IT as an enabler of curriculum redesign is not only efficiency but also effectiveness. Although institutions of higher education create, acquire, and transfer knowledge, they often lag businesses by approximately a decade in the adoption of new technologies. Since the global economy is making the transition from an industrial to an information economy, educational institutions have to make the transition from a curriculum based on one channel of learning (the instructor channel) and two primary “teaching technologies” (the blackboard and chalk) to a new computer-based curriculum. Internal and external pressures may explain the reasons for the recent and rapid interest of universities in applying information technology to teaching and learning. The steep reductions of funding and the change of students’ demography (part-time and working students) have led universities to consider information technology as a tool to automate learning and reduce costs. This vision based on cost-effectiveness and increased productivity will fail. As mentioned before information technology is not neutral. The application of information technology will bring not only a paradigm shift in learning and teaching methods, but also a paradigm shift in the way we think and build types of understanding. A review of the literature on learning theory has shown that there are many competing learning theories. Despite the lack of a unified theory, there is a consensus that the new technology is able to support seven learning processes (Alavi, 1994; Leidner & Jarvenpaa, 1993; Anderson and Reiser, 1995; Capell, 1995; Shneiderman, 1992b; Skillincorn, 1997): 1) cooperation and teamwork in learning; 2) engagement; 3) construction of knowledge, 4) learning style; 5) context or learning situation; 6) control of pace; and 7) adaptability. Recently, these processes have been timidly promoted, but there is a long way to go before we recognise fully the merit of the new processes and IT as an enabler. It is illusory to think that we can overcome rapidly and without major resistance centuries of traditional learning based on an accumulation of knowledge under three basics learning pillars of passivity, competitiveness, and individualism.

**Insight #2**

*The number and variety of learning channels have increased rapidly with the advent of hypertext, multimedia, hypermedia, Internet, and so on. With today’s computer based learning, the major choice is no longer whether to use the technology, but rather what technology to choose and what learning processes to transform in order to transform learning processes and improve the educational system’s outcomes.*
The design of the new curriculum should aim at promoting the use of the new technology to lay down, collectively or individually, new hypotheses and to test them. It is critical that the new curriculum identifies the new capabilities of IT that will support creative thinking and the questioning of misconceptions. The constructivist view involves learners to develop their own epistemological framework of thinking. The application of the new technology supports these varieties of epistemological frameworks. For example, IT can allow the learner to use simulation models to test different frameworks and reconcile gaps between a personal framework or personal mental model and the findings of others. Further, the learner is able to track down the sources of misconceptions and adjust his/her way of thinking. Tracking these sources includes thinking about the early schema (e.g., family education, early stories, etc.), the information itself, and the implication of these misconceptions.

**Insight #3**

*The curriculum must be redesigned around the capabilities of IT. The use of IT allows learners to define their own problems and seek their own solutions. This method of learning frees them from traditional and bounded frameworks of thinking and encourages them to seek solutions to new problems in a turbulent time.*

Learning does not occur when one accumulates knowledge, rather when knowledge is linked to other already acquired knowledge (Schank & Osgood, 1992). Information technology and its visualization capabilities increase communication richness. Future hypertext-multimedia-hypermedia systems would allow human images to be displayed in real-time as a person generates speeches. Because these systems will revolutionize product and process development, marketing, cyber leisure, learning, communication, and most importantly the kind of understanding, the curriculum designer must recognize the extraordinary impact of these systems on communication, relationships and thinking. The new curriculum, thus, must recognize visualization as a medium of communication and knowledge transfer.

**Insight #4**

*Language as a key mode of communication is a tool by which thoughts are expressed (Piaget). The new technology and its visualization capabilities may transform the way we communicate and acquire and transfer knowledge.*

Prior to the printing press the teacher was the unique source of knowledge acquisition. Although the invention of writing allowed part of the knowledge to be transferred asynchronously, the teacher maintained a dominant position as the main source of knowledge. The printing press has severed the human source from knowledge acquisition and transfer, but oral speeches continue to occupy a preponderant place in the actual curriculum. Television, audio and video recordings have further decoupled knowledge from the teacher. However, the new technology has the potential to decouple radically knowledge from the human source. As mentioned earlier, the application of these new technologies is not neutral. This means that the application of these technologies in education may decrease human interaction and involvement and increase quality education through standardization.

The decoupling brought about by electronic education will present new alternatives to the actual education system. The decoupling will bring to the learner's door internationally renowned educational institutions. Since the need to come to classrooms will cease or be limited, teachers will
be required to offer their courses on the web. One scenario would have virtual universities: constructed offering virtual courses to virtual students who will get a virtual diploma. The new curriculum will allow students and teachers to bypass bureaucracies such as universities, education ministries or others. Because students will be able to register and attend classes anywhere and at anytime, there is a potential that the university we know today will cease to exist.

Insight # 5

*Information technology will decouple knowledge acquisition, construction, and transfer from human sources to electronic mediums. The curriculum designer has to weigh carefully the ultimate consequences of the decoupling.*

The electronic education environment will create fears, resistance, and even sabotage. However, it is important to remember that the new technologies will also open up new channels of education to a much larger population around the world than before and create paths of education to all who desire to learn. The following citation sums it all: “Now some people regard technology as an enemy of individual freedom-the word conjures up huge, impersonal corporations, 1984-style totalitarian governments, and according to Hollywood lore, berserk computers that want to take over the world. Nothing could be further from the truth. Technology is in reality the mortal enemy of tyrants and bureaucrats; it doesn’t suppress ordinary people—it frees them from centralized control and gives them unprecedented power over their own destinies” (Malcolm, 1991).

Insight # 6

*Information technologies will open new channels of education that benefit a larger population around the world and give them the needed power to control their own lives.*

7. CONCLUSIONS

Information technology (IT) has the potential to provide rich, interactive, engaging, and creative learning environments. Depending on the learning vision, however, the impact may vary. From an objectivist view, the impact is to make the educational system more efficient. From the university and government perspective, efficiency refers to both cost and quality. From the societal perspective, efficiency refers to the accessibility of university education to a much wider range of people. From a constructivist view, the impact of IT is to enable learners to construct their own knowledge and build their own reality. Further, IT supports the collaborativism (learning through interaction among individuals) and socioculturalism (learning through historical and cultural development) models of learning. Finally, IT supports the Rousseauian view that recognizes learners’ freedom and natural development. The three basic views can be reconciled, integrated and supported by IT. The ultimate challenge of education is to balance the psychological, rational, and imagination dimensions and leverage them with information technology capabilities.

The conceptual model of computer-based learning developed here is an attempt to integrate these views and map IT capabilities into learning processes and in turn into learning outcomes. Direct IT mapping into learning outcomes may make delivery more efficient, but will not seize the full potential of IT to transform learning processes and develop new kinds of understanding. The inertia of universities and academia in general to adopt the new technology may not attributed to production and delivery requirements, but rather, the paradigm shift to new kinds of understanding. The major challenge of the new IT based curriculum will be to build a consensus about what the new kinds of understanding should be.
Annex A: Instructional technologies

The following seven instructional technologies that can be used to support learning:

Groupware: Groupware may be defined as computer-mediated collaboration that supports people activities and collaborative processes. One of many ways to understand the role of groupware in education is by the major role that it plays in breaking down barriers between educators and students, between research disciplines and, more importantly, between institutions located in different countries. Groupware allows people to create and propose ideas, projects etc. and communicate them through faxes, memos, and meetings (Dennis, George, Jessup, Nunamaker and Vogel, 1988). Since we can create, communicate, and keep track of information, groupware can break down not only barriers like time and place, but it also has the potential to break down political and cultural barriers as well. Universities can use groupware to build joint programs, connect classrooms to the same conference, and support debate among students or researchers located in different places and countries. Common groups can use video conferencing to increase face-to-face virtual interaction between people (Launon, 1992). Groupware is a powerful technology that can break barriers and significantly improve learning and understanding. Groupware is expected to encourage collaboration and social interaction. Therefore, groupware is linked to collaboration and socioculturalism, two views that are derived from the constructivist theory.

Electronic Performance Support (EPS): EPS is a variant of multimedia that can be linked directly to the task being performed. Lotus 1-2-3® is a good application of EPS. Since it is able to support engagement, adaptability, retention and recall, and real environment, EPS should improve learning motivation and optimize performance. EPS is more readily linked to the constructivist view. Despite the possibility of EPS as a promising learning technology, organizations are not yet willing to develop it.

Integrated Messaging: Integrated messaging combines electronic mail, electronic data interchange (EDI), facsimile document transmission, and other electronic forms of transmission through a unique electronic transmission medium. Integrated messaging provides users with integrated services that will facilitate the mechanisms of coordination. This can be of great help for courses that are based on collaborative efforts at multiple sites, where planning is crucial. or for courses that are designed to optimize feedback and promote the cognitive information processing model of learning. For example, one of the authors used E-mail as a support to communicate with twelve groups engaged in the completion of a course project. Students who tended not to participate in the class who were heavy users of the E-mail. It appears that students who are less sure on their proposals are more likely to use the E-mail to communicate with the instructor. The theory of media richness is not contradicted; the E-mail can serve as a medium to combat timidity and “confrontation.” It seems that the hurdle of “feeling stupid” is reduced. The authors also used E-mail successfully to monitor and coordinate research progress at distant universities located in Europe. Depending on the nature of the use, E-mail technology can support several views.

Simulation models: Simulation technology has long been established as a useful medium for assisting the user in obtaining insights into complex problems (Gorrell and Downing; 1989). The underlying assumption for using simulation technologies is that learners can learn best when they conduct experiments and gain knowledge through practicing. However, simulation modeling does not usually allow the learner to interact and participate when resolving a complex problem. This means that a good portion of the analysis appears to the learner as a “black box.” A new medium called visual interactive simulation is developing, which allows the learner to interact with the simulation model using prior and new knowledge to explore alternative strategies. Because the learner can interact and participate, the level of confidence in the system will increase. The visual interactive simulation approach can be used in conjunction with artificial intelligence. The integration of these two approaches adds capabilities that allow the learner to build systems graphically and learn about their behavior.

Virtual Reality: Virtual Reality (VR) is a computer-based technology where the learner interacts with a 3-D computer-generated environment. This technology gives the illusion of being immersed in 3-dimensional space with the ability to interact with the environment by moving around and controlling objects. VR is not widespread because it is relatively expensive and difficult to implement. However, it is expected that, within five to ten years, there will be many applications, particularly of a commercial nature. In the learning domain, this technology can provide a realistic context for the learner to acquire knowledge in history, language, medicine, engineering, and so on. In areas such as product development, marketing, and purchasing, the VR technology can provide extremely valuable insights to learners in engineering and business schools.

Simulation models and virtual reality technologies seem to be promising venues for education. Both models are based on the assumption that knowledge is constructed from experiences, mental structures, and beliefs that are used
to interpret reality. These two technologies support the imagination and constructivist view, and other linked views such as sociocultural.

**Intelligent Tutoring:** Intelligent tutoring support systems (ITSS) are computer-based learning systems that provide help and guidance to the learner in a manner comparable to an expert or a teacher (Seidel and Park, 1994). The "intelligence" of ITSS consists of diagnosing the responses of the learner in order to make eventually corrections. Further, ITSS attempts to deduce why the learner is making a specific mistake, since the system has the capability to reason as a human tutor would to provide insights and commentary to the learner about the causes of the mistakes (Livengood, 1994).

ITSS can fit a variety of views. An objectivist teacher can promote ITSS to the learner as a technology that helps knowledge transfer. In contrast to the objectivist, the constructivist may see it as technology that monitors the learner while he/she constructs his/her own knowledge and reality.

**Expert System:** The expert system (ES) is a system that captures human knowledge in a computer in order to assist learners and human experts. Because ES can perform better than the human expert in making judgements in a specific, usually narrow, area of expertise, it may have significant impact on individual learners operating in isolated environments. ES as a learning technology is based on the assumption that the accumulation of knowledge and experiences is the dominant factor for effective learning. Therefore, ES technology supports the objectivist view: in designing ES, learners are actively seeking expertise and judgements in problem-solving.

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