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Strategic Thinking †

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Abstract

Strategic thinking is one of the most complex cognitive processes which integrates time perspectives, entropy dynamics, nonlinearity, probabilistic approaches, intelligence and creativity. From an emotional point of view, strategic thinking requires a robust and optimistic approach, as well as a very strong motivation. Strategic thinking is concerned with future developments of present projects or organizations and its tries to formulate decisions for a dynamic, uncertain and risky future. Strategic thinking is a powerful thinking model which can be used successfully in research, engineering and management activities. The purpose of this paper is to present the main components of models of strategic thinking and to document their significance and contribution from cognitive and pragmatic perspectives. We take into consideration static and dynamic models, deterministic and probabilistic models, linear and nonlinear models, intelligent and creative models. Strategic thinking emergs as an integration of the most advanced of these thinking models.

KEY WORDS: (Strategic Thinking) (Dynamic Thinking) (Nonlinear Thinking) (Probabilistic Thinking) (Intelligent Thinking) (Creative Thinking) (Knowledge Management) (Strategic Management)

1. Introduction

For almost any major field of activity and for all organizations the external environment becomes more dynamic and uncertain. Turbulence and complex unknown reconfigurations of this environment, in a fast process of globalization increase the stress field of any competition and transform survival and competitiveness into major existential issues. Operational thinking by which we solve everyday problems and control a static environment is not any more enough. We need to develop a new way of thinking in order to understand ***entropic*** and ***discontinuous*** changes which may happen in the future and to be able to take decisions for a highly uncertain environment[1-3].

Strategic thinking might be a good answer to this above problem, since it integrates entropic thinking, nonlinear thinking, probabilistic thinking, intelligent thinking and creative thinking. It is well suited for the new world of knowledge which is developing very fast and for which we have to consider creation, conversion, sharing and efficient use of information and knowledge[4-6].

2. Thinking Models

We live in an Universe which is infinite in space, in time and in its complexity. However, people have wanted always to understand its reality and evolution. To understand this Universe we are living in is more than a necessity for our survival. We try to know and understand it by using the power of our mind and all the knowledge society has produced so far. Yet, our mind is finite. How then, can we understand such an ***infinite*** Universe with a ***finite*** mind? It seems like a ***knowledge paradox***.

The solution of this paradox is to construct ***thinking models*** as ***tools*** for approximating the real world. These models are developing continuously from our childhood through education in family, in schools, in universities and by direct experience of life. Also, culture, science and technology play a very important role in our understanding. The more powerful these thinking models are, the better our understanding of what happens in our environment and the more knowledgeable we become. Actually we see the real world through these models, like through some glasses. We may even consider these thinking models as cognitive ***lenses***. They also play a very important role in research as building blocks of

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meaning systems and ***value*** generators. They are inputs and outcomes for education and cognitive resources for developing our abilities. However, we hardly are aware of using thinking models, which have for different people, different ranges of cognitive power, dynamics, information entropy, complexity, efficiency and creativity[7,8].

3. Functional Structures

Thinking models are ***cognitive models*** able to approximate the real world and to help us understand the environment we are living in. Regardless of its specificity and approximation power, a thinking model is composed of three main functional structures: a knowledge basis, a set of inference rules and a set of fundamental reference values. From a dynamical perspective, the most stable functional structure is represented by a set of basic values. They are actually, cultural values specific for a given education which stand up as reference values for any decisions we make. Basic cultural values for an American thinking model might be different than those specific for a European model or a Japanese model. For instance, in the American model some of the most common values are individual working and competitiveness, while in the Japanese model they are team working and cooperation. Thus, for similar working contexts, the American thinking model may yield a different decision than the Japanese thinking model. Due to their highly specific cultural values thinking models cannot be transferred just as they are from one country to another. They must be adjusted according to traditions, culture and education specific for the host country.

Unfortunately, this is a very sensitive point about which many people do not think, trying to use foreign thinking models as they are. There is a very interesting story about Alexander the Great, who after defeated the Persian army ordered that all the dead bodies of the Persian soldiers to be burnt, like in his country. In this way, he wanted to show his military appreciation for all the dead soldiers. Unfortunately, the result offended the Persian army since they never burnt dead bodies because in their culture fire was pure and dead human bodies were not.

Basic reference values can be changed in time, but it requires a ***strong motivation, hard work and a stimulating environment***. It is very important to stress the fact that environment should be supportive and not resist such a change of cultural values. For instance, in the European former socialist countries building new economies based on new market values is a very difficult and slow process, because most of the old environment which still exists is not supportive. Thus, this transition to a new economy based on new economic and social values might take a generation to complete.

The set of ***inference rules*** contains all operations which actually contribute to information and knowledge processing, and decision taking. Here we find all the mathematical and logical operations we learned in schools and in universities. For instance, a simple inference rule could be a comparison of the type $A > B$. If we have a set of different numbers and apply this inference rule we end up with an ordered set of increasing/decreasing numbers. Using these inference rules we can perform any ***qualitative*** and ***quantitative*** analysis. Although it might be obvious, we have to stress the fact that not everybody has the same set of inference rules. For instance, some people do not know what an exponential function is, or what is the difference between addition and integration. For them, it would be very difficult to understand more complex phenomena like nuclear fission and fusion, or even a water steam explosion. These inference rules will make difficult the understanding, for instance, of the difference between linear and nonlinear processes and phenomena in Science, Engineering and life.

Let us consider a simple motion process for a given body's in a given system of reference and the change of this body position. If its motion is uniform in time, then the rate of change of this body position is constant in time and the rate of change of motion itself (i.e. the body acceleration) is zero. People who do not know anything about derivatives (i.e. inference rules) will have real difficulties in understanding change dynamics in any field of activity. Thus, the more complex these inference rules are, the more powerful the thinking model is.

There are many inference rules which we construct ourselves based on our ***direct experience*** of life. These rules reflect ***tacit knowledge*** and due to this fact they are sometimes difficult to explain. For instance, when a little child touches a flame with his fingers, it hurts and next time he will avoid touching a flame again. This is an inference rule he obtained by a direct experience, without any explanation given by his parents. These tacit knowledge based inference rules are very important for people who are living in a completely new and not so friendly environment and yet they must survive. It is a kind of Robinson Crusoe experience. We may think of the first expeditions for great geographical discoveries, of the first explorers to the North Pole, of the first man conquering Mount Everest, of the first man on the Moon etc. Successful people build their own inference rules and take good decisions which save their lives and contribute to their achievements. At the same time, many other people fail because they use their old thinking models for the new and hostile environment.

There are also inference rules established ***by legislation***, for a given social behavior. These rules contribute to implement and sustain a certain social order and they are specific to each country. To illustrate this point we may consider, for instance, the traffic regulations for driving automobiles on public roads and highways in a given country. A driver is supposed to learn and to obey to these traffic rules, without questioning their consistency, or logic. For instance, in countries like Great Britain and Japan drivers use the ***left*** side of the road, while in countries like France and Germany drivers use the ***right*** side of the road.

The third functional structure of a thinking model is ***the knowledge base***. It contains all the data, information and knowledge one person may have at a certain moment of his life. This is the most dynamic functional structure since it can always absorb new information and knowledge if there is a certain motivation. The more data, information and knowledge one may have, the more powerful his thinking model is. This knowledge base contains an important quantity and quality of tacit knowledge which has been obtained from a direct experience of life.

In a different perspective and at a different scale, we can talk about thinking models used in ***research***, performing different laboratory or numerical experiments. Based on these thinking models, which are actually ***cognitive approximations*** of real processes and phenomena, we develop mathematical and computational models and then perform simulations. We would like to emphasize the fact that the power of any research model and of any software package given is at the same time is limited by the power of the thinking model used. For instance, if we develop a software system to simulate a linear behavior of a solid body, although the physical process we are investigating is nonlinear, then the final conclusions will be restricted to linearity.

For such research models, the basic values are actually the basic concepts taken into consideration (i.e. linearity, nonlinearity, stationary, nonstationary, homogeneity, nonhomogenity, isotropy, elasticity, plasticity etc.). These basic concepts constitute the reference system for the interpretation of results. The inference rules are given by all mathematical formulations and equations which describe the physical phenomena and also, by all computational methods used for developing the software. These inference rules must be in accordance with the basic concepts used in the reference system. For instance, if nonlinearity is among the basic values, then we may consider nonlinear constitutive equations to describe material behavior.

The knowledge base for such a software package consists of all data and information which is already incorporated into the program and by the input data the user may consider. In this perspective, the power of such a software package is given not only by the input data and information, or by the efficient and sophisticated programming techniques used but also by the basic concepts used and by the power of mathematical models built in which allow researchers to describe more accurately real processes and phenomena, and to interpret more precisely the obtained results.

The question is how can we develop better and more powerful thinking models? The only answer we can provide is education in its broadest sense and continuous learning through all our life. The more powerful these thinking models become the more complex knowledge is processed and the better understanding we obtain.

4. Static Thinking

The simplest cognitive model is represented by static thinking. Its main characteristic is that ***time*** is not a fundamental variable of this model. The thinking process in a static mode is ***timeless***. That means that events and phenomena remain unchanged in time. Think of Mount Fuji, for instance. We can admire the same beautiful image anytime. Of course, there are some differences between summer and winter due to presence or absence of snow, but the mountain itself does not change. Actually this very basic feature made this famous mountain a symbol for Japan throughout its history.

Let us consider another example. When we come late evening at home and the light is off, we know where the light on/off button is and we switch it on. How do we know? We use a static thinking and as a result we consider that all things remained unchanged into their positions since we left the house early in the morning. Thus, static thinking gives us a sense of ***stability and safety***. We do not worry about what happens in our absence since objects are motionless.

Let us think of our history some centuries ago, when people used horses for transportation and road conditions were very bad. People during those times, with the exception of military expeditions and wars, used to spend all of their lifetime in the same community and place. Their life was village centered and they became so much accustomed to this static style that their culture developed certain values for the ***conservation*** of it. Even today, there are cultures which praise living in the same place throughout life and which consider any potential new visitor as an intruder. These cultural values have the same root and meaning: static thinking.

However, any event development in life or any phenomenon in nature involves change, and ***change*** can occur only ***in time***. There is no possible change in a static environment. As a result of this situation, a static thinking model ***cannot accept change*** and ***it cannot explain change***. People who are dominated by static thinking will be afraid of any change and they will oppose it. This is one of the main reasons why the adaptation of social, economical and political life in the European former socialist countries is such a slow process. The static thinking model which has been overemphasized in children's education generated strong ***inertial forces*** which oppose present social changes. Actually, static thinking generates an easy ***predictable behavior*** of people which is an excellent feature for any control system. Thus, there is no wonder why it has been overused and overemphasized in the former socialist education systems and cultures. Static thinking is useful for performing routine activities, but it is a very serious drawback for activities which involve change. For these last classes of activities we have to use other thinking models.

5. Dynamic Thinking

Dynamic thinking models ***do incorporate time*** as a fundamental variable. All events and processes develop in time since they generate change[9]. Time becomes a ***measurable*** dimension. We know from Physics that time is a one dimensional environment, while space is a three dimensional environment. Time can be characterized by a direction of evolution or not. When a process can develop from an initial state to a final state and then can develop in the reverse direction going through all same intermediate equilibrium states until it reaches the initial state, it is a ***reversible*** process. Otherwise, it is an ***irreversible*** process.

All processes we know in life, society and nature are irreversible processes. Biologically, we grow and get older and never can reverse our life into childhood. Even from ancient times philosophers observed that one cannot swim in the same water in a given river since change generates irreversibility. In this perspective, reversibility is a theoretical approach used in Thermodynamics for ideal processes, in order to simplify mathematical solutions.

Let us consider Osaka and Kyoto as two fixed points and a car moving with a constant speed between them. If we consider a very simple dynamic correlation between time, space and speed and all of them are constant, then there is no difference between going from Osaka to Kyoto or from Kyoto to Osaka. For these above given conditions, the process might be considered reversible and its thinking model as a dynamic equilibrium model. Time appears here only as a period which measures the ***interval*** elapsed between the initial and the final states of this physical process. However, in the real life, the actual driving time depends on traffic conditions and weather conditions, and driving from Osaka to Kyoto is not exactly the same as driving from Kyoto to Osaka. Real driving of the car is an irreversible process and we have to understand this fact.

We are living in a highly nonequilibrium mode and strongly irreversible world. Time means more then just intervals elapsed between different moments or stages of some considered processes. Time has ***direction***, from past toward present and from present toward future. We may say that real processes have orientation or direction in time. Such irreversibility in our world can be measured by using ***entropy*** in a broad sense, a concept introduced first in Thermodynamics and then generalized in many other fields of science and engineering. Actually, the entropy measures the degree of irreversibility for a given process and not its absolute irreversibility. Since irreversibility generates a kind of history of developing different processes, scientists say that entropy reveals a kind of ***time arrow***. It shows the direction of future development. Since real processes are irreversible and they develop in highly nonequilibrium environments, we have to develop thinking models able to make us understand these real processes. These models contain an oriented and measurable time axis, a fact for which we may call them ***entropic thinking models***[8].

Let us consider some examples from our field of research. If we consider a mathematical model able to describe stress and strain fields generated during a welding process within an elastic body and we do not consider any plastic behavior or change in phase, and there are no physical constraints for the boundary conditions, then from thermal point of view we may consider ***heating*** and ***cooling down*** of this body as two components of a reversible process. The knowledge model used in this above research has a dynamic equilibrium thinking model and as result, any interpretations are bounded to it. It will be a mistake to generalize our simulation findings beyond initial assumptions. If we complicate our mathematical model taking into account irreversible aspects of the welding process, then we use an entropic thinking model and we are able to simulate and evaluate the residual stress due to the input heat. Thus, our ***knowledge based research model*** can approximate real phenomena in a better way, enabling us to find adequate solutions for practical problems generated in industry by welding[10].

In any production engineering field or any management activity people do make decisions which have consequences. These ***decision making processes*** are irreversible and we have to develop entropic thinking models in order to understand and to find the best solutions. Otherwise, we may be confronted with serious risks. Developing quality management which is based on continuous improvement or ***kaizen*** becomes possible only in a management environment based on entropic thinking, since it is the only one oriented toward the future and it allows us to establish targets and to elaborate strategies for future achievements[11, 12].

We would like to emphasize the fact that although this above analysis may seem obvious, it is not. School education contributed very little in developing our understanding for a strongly dynamic and entropic world, and for developing necessary abilities for future oriented thinking and decision making.

Entropic thinking is also very important in adaptation processes, ***adaptability*** becoming one of the most important characteristics of our personality and of our organizations in this globalization process and increased international competition. Even in research we have to adapt continuously our thinking models to new market problems and to new economical conditions.

6. Linear Thinking

Linear thinking models are used to approximate complexity in our environment. We frequently use linear segments to approximate curves of different shapes. Basically, linear thinking assumes that for a given transformation process, the output variables are ***proportional*** to the input variables. Thus, if we know the input variables and the process constants we just multiply them and get the outputs variables. It is such an easy thinking model that most of our everyday life is based on it. Eventually, we may believe that it is the only way of thinking. All measurements systems are developed according to linear thinking. Let us consider measuring the temperature of heated water. The thermometer we use, regardless of its units given in degrees Celsius or Fahrenheit has a scale based on a linear equation.

Purchasing goods by measuring their mass it is also a linear process. If we buy a quantity Q (kg) of apples and the market price of them is P (Yen/kg), then we have to pay a total sum of money S (Yen) given by the linear equation: $S=QxP$. However, if purchasing is based on negotiations, then it is not anymore a linear process.

In research, we use frequently linear models to express physical material properties and their behavior under different fields of mechanical, thermal or electromagnetic forces. Let us consider, for instance, a bar of steel which is fixed at one end and free to move at the other end, and it is heated uniformly. This bar experiences a thermal dilation process, which is a linear process. Its elongation due to thermal dilatation is proportional to the temperature difference of the heated bar. Actually all linear elasticity modeling is based on linear thinking models.

There are many other fields of activities where people are using linear thinking, without even questioning its legitimacy or accuracy. For instance, budgetary salaries are based on linear thinking, making hard any differentiation among different people according to their individual experience, competence, contribution and performance. Due to this fact, incentives and motivation are very low in such budgetary systems, by comparison with ***performance based evaluation*** and payment in business organizations.

The most characteristic operation in linear thinking is ***addition***. In linear models it is using ***the principle of superposition*** we learned in high school. This principle is frequently used also in research, when we decompose a complex problem into several smaller problems and find first their solutions. Then, we just aggregate these simple solutions to obtain the solution of the initial complex problem. This approach works well as long as the real problem expresses some linear phenomena. Otherwise, this approach is misleading.

Linear thinking is used usually in quantitative analyses and not in qualitative ones, since ***quality*** is not a linear concept. Linear thinking is adequate for predicting future outcomes by using extrapolation techniques. Whenever we use such techniques we must be aware of the fact that real life is not linear and we perform only some approximations to it. Thus, interpretations of the results should be made carefully and it is recommended to avoid any generalizations for situations not researched yet. However, ***predictability*** is a basic characteristic of linear thinking and one of its main attractions, especially in control engineering.

7. Nonlinear Thinking

Biological and psychological phenomena, as well as many social and natural processes are nonlinear. When their departure from a linear mode is significantly large we must use nonlinear thinking. This means using correlations between output variables and input variables which have ***nonlinear mathematical formulations***, like polynomials, exponentials, logarithms, sine and cosine functions, integrals, derivatives etc. Of course, this is a more difficult approach but may be closer to real phenomena. The point we try to make is that a person who thinks only in a linear way cannot properly understand complex phenomena which have a nonlinear nature and he will try to evaluate them by using simple linear models.

Let us consider a coffee making machine. Water is heated from the room temperature up to 100 degree Celsius. During the heating process temperature is increasing linearly with the energy of water, which increases with the heat input. When the temperature reaches the saturation point of 100 degree Celsius, it stops. However, heat continues to increase the water energy. Water is transforming into steam. We say that water performs a ***phase change***, which is strongly nonlinear. If our thinking model cannot accommodates and explain such a nonlinear phase change, we cannot understand what actually happens. If the boiling water is contained in a closed vessel, phase change produces steam which builds up the pressure inside. If the pressure becomes higher than the strength of the vessel walls, then a steam explosion will occur.

Intellectual and ***creative processes*** are highly nonlinear. It is a mistake to evaluate them based on linear models. Yet, we may recall that about 20-30 years ago, when programming was a job in itself, programmers were paid proportional to the number of program lines they wrote. Thus, a highly nonlinear activity has been evaluated by using a linear thinking model. As a consequence of this mistake, programmers were interested to increase the number of lines, in order to show how much they worked. Eventually, they produced programs with huge numbers of lines which increased the computational time and thus, increased their inefficiency.

Innovation and creativity are highly nonlinear processes. Thus, for a successful management which develops innovative strategies in order to obtain a strategic competitive advantage nonlinear thinking is the only possible approach[13-15)]. At the same time managers must develop new metrics for progress evaluation and for excellence stimulation. Linear metrics proved to be not suitable for these new phenomena. Quality management based especially on the continuous improvement concept, known in many fields of activity as the Deming cycle: ***plan-do-check-act***, can be developed and applied only as a nonlinear process[16, 17)].

Knowledge engineering and management are also highly nonlinear processes. Knowledge, unlike physical quantities cannot be increased by addition or superposition effects. If two persons are talking and they produce individual knowledge quantities A and B, respectively, the total quantity of knowledge exchanged is not equal to A+B. Thus, to understand and to make efficient knowledge creation, in conversion and sharing processes people should use nonlinear thinking models[18-21)].

Education in Science and Engineering is concentrated mostly on information and explicit knowledge transfer from professors to students. However, good scientists and engineers should have also developed certain skills and capabilities which are highly nonlinear. They must be able to integrate the explicit knowledge they get from professors and from books with their own tacit knowledge and with the experience they get, converted or transferred from their professors. Thus, transferring such kinds of skills and experiences from one generation to another requires nonlinear thinking models and nonlinear educational approaches[22)].

Nonlinearity is a characteristic of many processes we try to model and simulate numerically in our research. Thus, we must pay attention to any assumptions we make and to any mathematical and computational methods or techniques we use in our research such that we can reflect nonlinearity in the final results. We may have physical nonlinear properties, geometrical nonlinear shapes, functional nonlinear processes, analytical, numerical or computational nonlinear procedures. For example, if a given software program simulates a welding process but it does not include phase change or plasticity, its solutions will not reflect typical nonlinear aspects of the welding process and the simulation power of such a computer program is rather low. Also, the procedure of ***decoupling*** thermal from mechanical phenomena in order to reduce computational time can be done only when nonlinearity is rather low. Otherwise, we gain in computational speed but we lose in accuracy of representing nonlinear features of the welding process.

8. Deterministic Thinking

The deterministic thinking model is based on the idea that things and events must be well ***defined*** and ***determined*** before they happen. Actually, they happen due to our way of determining them. Their occurrence is certain. That means that their probability of happening is always equal to one. Also, we may say that the chances for such event to occur are 100%. There is no uncertainty and thus no risk associated with such deterministic thinking. For instance, 2+2=4 is true anytime. There is no question about it.

Actually, deterministic thinking is a ***social invention*** made in order to reduce chaos and to enable some kind of activities to take place. One of the best examples of deterministic thinking is the time schedule for trains and for airplanes. Without such a time schedule no coordination of their circulation or flight can be done. Another deterministic thinking model is the daily working program of a given company, or the time schedule for students and professors.

Deterministic thinking is necessary in organizing the traffic on public roads and highways. We have already referred to this aspect when we talked about the basic values of a thinking model. However, the rules established for car driving by legislation is a clear model of deterministic thinking. And we have to emphasize the fact that we need such kinds of thinking at social levels. Otherwise, how would drivers proceed if traffic rules had been formulated in a different thinking model. For instance, how would it be if the rules said that in Japan driving on public roads is on the left side with a probability of 50%?

Actually legislation promotes deterministic thinking, as well as some unwritten rules which come from history and try to introduce order in social behavior. We learn all of these rules in schools or later in our life and do our best to respect them. The question is ***how much*** of our social life, organizational life or family life should be strongly ruled by such a deterministic thinking? We should not forget that deterministic thinking, excessive discipline and order in any organization kill incentives and innovation which might produce outcomes in conflict with the well established order. Taking into consideration this aspect, many entrepreneurial companies which encourage creative and nonconventional thinking relaxed many of the organizational rules concerning a fixed daily working program and many internal structural hierarchies and changed rigid deterministic rules with a flexible and stimulating management environment.

Deterministic thinking has been used extensively by ***scientists and engineers***. Most of all the Science laws we studied in schools and universities are actually a product of a deterministic thinking. Let us consider for instance the law of mass conservation in fluid mechanics or Hooke's law in solid mechanics. Both of them express correlations which are well defined and which yield the same results for similar problems when we consider the same geometries and same boundary conditions. Without these laws and mathematical equations engineers could have not created machines and developed so many technological systems we are using today. Then, what is wrong with deterministic thinking? Nothing in itself, since we need such kind of thinking. But trying to overuse and to impose it more than is necessary this kind of thinking we might lead us to consider that our live cannot be changed and nothing can be done to improve it from social, economical, educational and technological point of views since everything is pre-determined and transcends our power. Deterministic thinking is a sure killer of creative and innovative thinking and a sure enemy of accepting change which brings in uncertainty and risks.

9. Probabilistic Thinking

In nature, society and life events do not have certain outcomes. Event occurrence has a probabilistic nature and events may happen with different probabilities. One of the best known examples is the weather forecast. We learn from TV programs or from newspapers what the weather will probably be next day, but nobody can assure us that the forecast is going to be 100% accurate. To understand and to properly use such a weather forecast we must develop probabilistic thinking. This means accepting the fact that some events or some outcomes may happen with different ***probabilities***, which actually means accepting the uncertainty related to their occurrence. However, any uncertainty has an ***associated risk*** that we must understand and at the same time we try to reduce the possible negative outcomes generated by this risk[23]. Thus, probabilistic thinking is much more difficult and sometimes it is hard to accept, but developing such kinds of thinking models we will be better prepared for a future which is by its own nature ***unknown and uncertain***.

For any company or nonprofit organization the external environment becomes more dynamic and changeable, which means more uncertainty for its future configurations. In order to understand this new trend and to take sound decisions concerning future developments of our activities we must be able to deal with ***probabilistic events*** and with their ***associated risks***. That means to develop our ability to identify potential risks, to evaluate their magnitude and to conceive measures to reduce possible negative consequences. Let us think of some natural disasters as earthquakes, tornados, typhoons etc. Their occurrence is highly uncertain, but if we understand their nature and their impact on our houses, cities, transportation systems, bridges and living conditions we may be able to develop some technological systems or managerial programs that reduce their destructive force.

In our research models we usually input known and well defined loads. However, in order to approach reality much better we have to develop probabilistic models able to accept as inputs loads which are uncertain in magnitude and in their occurrence. Think of the wind forces, of the ocean wave forces or of the tremendous forces generated almost instantaneously by earthquakes. All of these forces must be taken into consideration as probabilistic events when we simulate and design buildings or any technological systems in environments with such kind of natural phenomena, like in Japan. There is no way to take safety measures and to reduce risks for such kind of situations using a deterministic thinking approach.

One may asks how it is possible to develop such kind of probabilistic thinking models in schools or universities. It is not so easy and it requires a ***nonconventional*** approach from professors and authors of textbooks. For instance, if in a Physics book a student finds some problems to be solved by simply using given formulas, then his mind will be trained for a deterministic thinking. Now, let us consider the same problems but with incomplete data and with several possible answers. In such a situation students must input by themselves some necessary data based on their own learning experience and then solve these problems for different outcomes. Also, they have to provide interpretations for each solution and to judge their accuracy. Such a kind of education is much more difficult, but finally students will be able to develop their own thinking and in a probabilistic way.

10. Intelligent Thinking

Intelligence and creativity are highly difficult concepts to define and to operate with. In real life, intelligence implies creativity and creativity implies intelligence. There is no clear cut distinction between them. However, from our analysis point of view we may consider intelligence and creativity as two distinct concepts which are ***complementary*** one to each other.

Intelligent thinking involves a thorough analysis of many possible combinations of known data, information and knowledge in order to yield an ***optimum solution***. Intelligent thinking is searching beyond the obvious facts and tries nonconventional way of combining things such that it becomes possible to reach to an excellent answer, nobody was thinking of[24]. However, we stress the fact that intelligent thinking is operating with ***known*** explicit and tacit knowledge. There is no new knowledge creation.

To illustrate this point we shall recall a story about Edison, when he was working on improving the glass bulb geometrical shape of the electric lamp. Dealing with a new shape of such a glass bulb, Edison one day asked one of his young researchers to estimate the volume of that bulb. His researcher tried to compute that volume using some mathematical formulations, but it was very difficult due to the special shape of that electric bulb. Edison took a different approach. He filled that glass bulb with water and then put it into a glass cylinder used for measuring water volumes. He obtained a very accurate answer in a very short time, in a way his young researcher was not able to think about. This is an example of an intelligent solution to a rather difficult mathematical problem and for which Edison used only known elements.

Intelligent thinking is very ***flexible*** thinking which searches for many alternatives of the given problem and many possible combinations of all known data, information and knowledge such that from all these combinations it is possible to produce the best answer. Intelligent thinking cannot be developed and used in static and deterministic environments characterized by mediocrity. Actually these types of environments develop attitudes of obedience and passive behavior and usually they do not encourage intelligent thinking. Working in nonprofit organizations with well developed bureaucracies is like working in prohibited environments for intelligent thinking, since they promotes only deterministic thinking models to conserve their hierarchies and power.

Intelligent thinking is well received in research environments. Here it is very important to find all possible combinations for the given facts and information and to find the best interpretations for the laboratory or numerical experiments done.

11. Creative Thinking

Creative thinking implies production of ***new knowledge***. When this quantity of new knowledge is rather small we talk about an ***innovation***. In this situation we are looking for improvements to the known technologies or scientific explanations about natural or technological processes and phenomena. When this quantity of new knowledge is significantly large, contributing to a new product or technology we talk about an ***invention***. Inventions are produced less frequently than innovations, since they need an accumulation of a critical mass of new knowledge in a certain domain of activity. In Science, when we deal with something completely new we talk about a ***discovery***.

The production of new knowledge can be achieved by continuous increments or by significant jumps. Knowledge creation becomes more and more important in any field of activity, but mostly in R&D due to stronger competition forces and globalization processes. Creative thinking is mostly needed when we are experiencing changing environments, characterized by new aspects and phenomena. Providing old solutions for new problems might be impossible sometimes. Thus, we have to open new perspectives to produce new knowledge. Creative thinking does not provide the best solution for a given problem, like intelligent thinking does, but it provides a new way of solving a problem or even a complete new solution[25]. Thus, in order to obtain the best solution and to open at the same time new ways of improving it in time, it is necessary that intelligent thinking and creative thinking to operate in an ***interlinked*** mode.

Many people associate creative thinking with famous names like Edison, Bell, Ford and many others in technology or with Newton, Euler, Einstein, and many others in Science. However, creative thinking is not a capability that only some people may have by birth. Creative thinking is a capability which anybody can develop and use, of course at different levels and intensities. Education plays a very important role in developing creative thinking. Also, ***organizational culture*** is very important in stimulating and rewarding creative thinking. Companies like Walt Disney, 3M and Microsoft are well known for their creative thinking approaches and for their innovation strategies. Also, many Japanese companies make great efforts to implement creative thinking models such that ***knowledge creation*** and ***knowledge conversion*** from tacit to explicit to become more and more important in their organizational life[18, 26].

Creative thinking is basically an ***optimistic*** thinking model since it is able to find a solution to a new problem by creating new knowledge if the known knowledge is not enough. This is also characteristic for research, when using known methods and software programs to simulate ***new*** phenomena may come to an end, and only by using creative thinking can be found new ways of solving the problem at hand.

12. Strategic Thinking

Strategic thinking represents an integration process of the most advanced thinking models we have presented above. Strategic thinking is ***a projection in time*** of our thinking. Thus, if operational thinking models characterize our understanding of events and processes which have been produced in the past or they are developing now in this present time, strategic thinking is concerned with what may happen in future time. This future projection can have usually a span of 3-5 years[16, 27].

Strategic thinking is a ***target oriented*** process and thus it must contain the entropic thinking. If we want to think for the future, then we must accept change and a given direction of it. That means that static thinking cannot be associated with strategic thinking and that we consider irreversible processes and their development from past to present and from present toward future. Time is very important as ***a measure*** and as ***a direction*** of development and improvement. Also, it is important to think of change not as a uniform variable process with zero acceleration, but as a variable process with its own rate of change (i.e. acceleration is not zero).

Strategic thinking must be able to approach the complexity of real life, thus it cannot be linear. It incorporates ***nonlinear thinking*** with all its variety of shapes and functional structures (i.e. polynomial, exponential, integral, differential etc.). We have to make a special emphasize on ***emotional*** and ***behavioral*** models which are by definition nonlinear. Here we would like to emphasize the importance of skills and experience which are based on tacit knowledge and which represent strongly nonlinear fields. Strategic thinking is basically a ***cognitive*** activity, thus dealing with ideas and knowledge which cannot be processed linearly. Knowledge management and change management are highly interlinked with strategic management and all of them need nonlinear thinking and a dynamic approach. Striving for ***excellence*** and for ***competitive advantages*** requires also a good understanding and control of strongly nonlinear processes placed within a highly uncertain domain.

Strategic thinking helps us to shape and to construct structural and functional order for the future. But the future is a complete unknown domain. Of course, we would like to consider this future known but the truth is that it does not exist at this moment. We construct the future in our ***mind*** using different thinking models, but we have to point out the fact that we don't have any power to control it as we would like to. Future means ***uncertainty and risks*** and in order to understand that and to develop plans and solutions, we need to develop a probabilistic thinking model. Thus, strategic thinking incorporates probabilistic thinking and makes use of it in developing strategies for achieving the goals we have established. Also, we try to identify all major possible risks and to evaluate them to our best ability. Knowing these possible risks we can take measures to avoid or to reduce their negative consequences.

Strategic thinking is based on intelligence and creativity, because it searches for the ***best outcomes*** and for creating new knowledge when it is necessary. Taking into account how fast things change today, we may say that the future is coming to us like a shock wave. Only by developing our capability of generating new knowledge and skills may we find the answers we need for survival and for the challenging competitions that will come in the future[28-30].

Strategic thinking is necessary also in planning our research programs for the next 3-5 years. We have to think about not only how to solve better the known problems put forward by industry to us, but also about what kind of new problems will be of interest for future industrial developments. Thus, ***strategic research*** will be exploring completely unknown fields of problems and solutions. Preparing for the future means not only to perform good operational research, but also to develop strategic research by stretching out our minds.

Strategic thinking is more than just a thinking model. It is as well an ***art*** of thinking[4)]. It has been used throughout the history by great generals as Alexander the Great, Ceasar and Napoleon, or by great warriors as Miyamoto Musashi. This art consists in projecting into our mind events and processes before they may happen. As Musashi explained in his book, a true great warrior is winning a fight first into his mind and then on the battlefield[31)]. Today, in many schools of business and management, students and executives study new approaches to developing this art of strategic thinking based on great warriors' and generals' experience[32, 33)]

13. Summary

The knowledge paradox challenges the fact that the Universe in which we are living is infinite in time, space and in its complexity, while our mind is finite in both biological and psychological dimensions. The only way we have to understand this Universe is by developing thinking models as cognitive approximations of the real world. The better these models are, the better our understanding is.

The purpose of this paper is to present some of the most important thinking models we currently use and to analyze the functional structure of strategic thinking. We present static and dynamic thinking models, linear and nonlinear thinking models, deterministic and probabilistic thinking models, intelligent and creative thinking models. Finally we explain what strategic thinking is and how it is obtained by integrating the most advanced thinking models. We consider some significant examples in order to illustrate each of these thinking models.

Strategic thinking is a projection in time of our present thinking. It helps us to construct structural and functional order for an unknown and uncertain future. If we can understand and develop our strategic thinking then we shall increase significantly our chances for a better future and a better life.

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