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Knowledge as Energy: a Metaphorical Analysis

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Abstract: The purpose of this paper is to perform a metaphorical analysis of *knowledge as energy*. This paper is based on a theoretical research concerning the nature, perception, basic laws and challenges brought up by these fundamental concepts of *knowledge* and *energy*. The metaphorical analysis of knowledge and intellectual capital has been initiated by Daniel Andriessen and his findings have been presented in several seminal works (Andriessen, 2006; 2008; Andriessen and Boom, 2007). In his work, Andriessen concluded we need to find new metaphors for knowledge. In our theoretical research we shall consider the *knowledge as energy* metaphor, with *energy* as the source domain, and *knowledge* as the target domain, and we are interested in identifying the metaphorical semantic kernel and the limitations of this analysis. The semantic kernel contains: (1) the concept of *field* as a nonuniform and nonlinear distribution of knowledge; (2) dynamics of potential and kinetic forms of manifestations; (3) dynamics of work and heat, and (4) entropy and syntropy process characteristics. Limitations of this analysis come from the conservation laws of energy transformation which cannot be applied to the knowledge domain.

Keywords: Knowledge, tacit knowledge, explicit knowledge, energy, entropy, metaphorical analysis.

1. Introduction

We are living in a very complex world. It is infinite in any meaningful direction we may consider. However, from biological and psychological point of view, our brain power is limited. Our effort to understand such an infinite world using a finite mind looks like a living paradox And the only way to escape this paradox is to construct *thinking patterns* or *mental models* (Bratianu, 2007a; Gardner, 1993; Gardner, 2006; Senge, 1990; Sherwood, 2002; Simon, 1996). These thinking patterns are cognitive approximations of the real world, which have been developed through our education in family, school, university and a given cultural environment. As Senge (1990, p.175) remarked, our "*mental models determine not only how we make sense of the world, but how we take action*". Among many such mental models, *metaphors* play an important role in understanding new phenomena, structuring our thinking and developing new concepts (Lakoff and Johnson, 1999). A metaphor is not just a semantic similarity between two concepts, but an instrument to develop a new cognitive approximation using a well known concept. It helps in providing a perspective for the new concept, emphasizing certain key characteristics and ignoring others.

Andriessen (Andriessen, 2006; 2008; Andriessen and Boom, 2007) has shown that the conceptualization of knowledge in knowledge management and intellectual capital literature is primarily based on metaphor. In the West, dominant metaphors of knowledge are based on the idea of knowledge as stuff. He concluded that to bring progress to the field we need to find more new non-stuff metaphors. In our theoretical research we shall consider the *knowledge as energy* metaphor. The source domain is represented by the concept of *energy*, and the target domain is represented by the concept of *knowledge*. The metaphorical semantic kernel is given by the intersection of the two semantic domains (Andriessen, 2007). The larger this semantic intersection, the better cognitive approximation we get by using this metaphor. At the same time, there will always be some characteristics of the source domain not used by metaphor, as well as some characteristics of the target domain not covered by the source domain (see figure 1).

It might be of interest to recall the fact that the concept of energy as *heat* has been introduced into science by using the concept of *fluid* as a metaphor: "*Heat was regarded as the energy of motion of the tiny particles or molecules of which a body is composed. In the eighteenth century, however, the kinetic theory of heat lost favour and was replaced by the conception of heat as an imponderable, self-repellent, indestructible fluid, which was given the name of caloric by Lavoisier*" (McKenzie, 1960, p.164). In the beginning the metaphorical entailments proved to be valuable, but when new

discoveries in physics had to be explained, the caloric metaphor showed its limitations and the substance-like explanation should be replaced with that of a field.

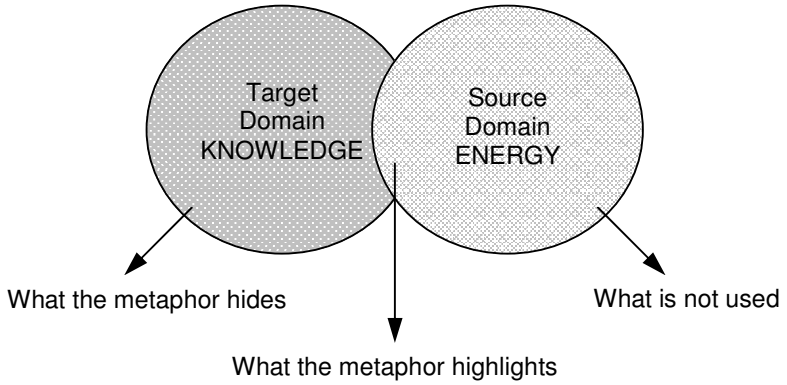

Figure 1: Source and target domains of the *knowledge as energy* metaphor

Energy is a field with no mass, yet it is related to mass through the Einstein famous formula. Energy cannot be created or destroyed. It can be only transformed according to the law of conservation, regardless the practical forms of energy available. Energy can be characterized in both intensive and extensive dimensions, and it can be found in this world in many forms. Mechanical energy can be found as potential or kinetic energy. Potential energy can be transformed into kinetic energy and vice versa. The distribution of energy and its transformation patterns can be characterized by the entropy level. *Knowledge* is a non-substance entity and thus it can be considered as a field. It can be created and it can be destroyed. Thus, we cannot conceive any conservation law for knowledge. Knowledge may have intensive and extensive dimensions, but they must be defined in a different way. Knowledge can be tacit and explicit. Tacit knowledge can be transformed into explicit knowledge and vice versa. Finally, the entropy may be used to characterize the degree of structuring of knowledge field and the irreversibility of knowledge transformation processes.

In the remainder of this article we will explore the metaphorical entailments of the *knowledge as energy* metaphor, as well as describe the elements that are not used from the source domain and the elements that the metaphor hides.

2. The metaphorical entailments

2.1. Knowledge as a field

The first characteristic from the source domain we point out in the target domain is the *field* manifestation of the energy. Thus, *knowledge should be considered as a field*. A field of forces is by its nature mass free and spread in space as a continuous domain.

Andriessen (2006, 2007), Andriessen and Boom (2007) showed in their analyses that the dominant view in the western thinking is the metaphor of knowledge as an *object* that can be created, stored, shared, located, moved, controlled and manipulated. These attributes have been associated to individual and organizational knowledge in the effort of explaining the resource functionality of the knowledge. In their frequently referenced book on working knowledge, Davenport and Prusak formulate the following definition: "*Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information*" (Davenport and Prusak, 2000, p.5). The metaphor used is a strange combination of fluid which is a physical object and a mix of experience, values, contextual information and expert insight which are non-physical entities. In other words, it is a dualism similar to that used in defining light as being both substance and non-substance at the same time. In the eastern works dedicated to knowledge and knowledge management, the metaphors used are those of *spirit* and *wisdom*. Both concepts have a spiritual nature which means actually a non-substance or field characteristic. To understand better what a field means, let us consider the gravity field. We are living every moment of our lives and everywhere on Earth in this gravity field, without a conscious

representation of it in our minds. However, we feel it anytime we jump, or we want to take in our hands a heavy weight. In views of Nonaka and Takeuchi, "*Highly subjective insights, intuitions, and hunches are an integral part of knowledge. Knowledge also embraces ideals, values, and emotions as well as images and symbols. These soft and qualitative elements are crucial to an understanding of the Japanese view of knowledge*" (Nonaka and Takeuchi, 1995, p.9). Thus, the field characteristic of the energy metaphor is very close to the Japanese interpretation of knowledge. Knowledge is not anymore a set of puzzle pieces a student acquires during his studies, but an inner field of experiences, images, symbols, information, values, thoughts and feelings which is open toward the external spiritual field. Actually, this dynamic interface between the individual inner field of knowledge and the external field of knowledge explains the cultural dependence of knowledge and its different interpretations. We know that any action against the gravitational field can be done only by consuming a certain amount of mechanical work. In a similar way, changing the cultural field by any individual who decides to live in another country than his home country involves a great deal of cognitive and emotional work, since cultural values act as powerful knowledge attractors.

2.2. Tacit and explicit knowledge as potential and kinetic energy

In the source domain, there are two forms of mechanical energy: potential and kinetic. *Potential energy* is the energy embedded with a body as a result of its positioning within the gravitational field. The magnitude of potential energy is proportional with the height the body is lifted up from the surface of earth. Changing its position produces a proportional change in its potential energy. Think of the water in a lake of accumulation which falls down on the blades of a hydraulic turbine. The initial potential energy of the water in the lake is maximum, and then it starts decreasing as the water is flowing through. Actually, the potential energy is transforming into kinetic energy, according to the law of conservation. *Kinetic energy* is associated with the motion of the body, and through its variation the mechanical work is produced. Kinetic energy can be also transformed into potential energy. The total mechanical energy of a generic body is given by the relation:

$$E = EP + EK \quad (1)$$

where: E – total energy; EP – potential energy, and EK – kinetic energy. According to the law of conservation the total energy E remains constant when potential energy EP is transforming into kinetic energy EK, or vice versa.

In the target domain, there are two forms of knowledge: tacit and explicit. For tacit knowledge we may use the metaphor of potential energy, and for explicit knowledge we may use the metaphor of kinetic energy. As Polanyi remarked, "*there is a great deal of truth in mechanical explanation of life*" (Polanyi, 1983, p.42). Tacit knowledge "*is personal knowledge embedded in individual experience and involves intangible factors such as personal belief, perspective, and the value system*" (Nonaka and Takeuchi, 1995, p.VIII). Being highly personal, tacit knowledge is hard to be formalized and communicated or shared with others. Also, subjective insights, intuitions, and hunches fall into this category. It is deeply rooted in an individual experience, which reflects actually its positioning with respect to a certain cultural environment, similar to the potential energy dependence to the body position with respect to the gravitational field. The magnitude of tacit knowledge can be increased by increasing one individual's experience. Explicit knowledge "*can be articulated in formal language, including grammatical statements, mathematical expressions, specifications, manuals and so forth. This kind of knowledge thus can be transmitted across individuals formally and easily*" (Nonaka and Takeuchi, 1995, p.VIII). Explicit knowledge is associated to the decision making process and to action. It is a dynamic form of knowledge which is able through its variation to generate decisions and actions in the way kinetic energy generates mechanical work as a result of its variation. Tacit knowledge can be transformed into explicit knowledge through the externalization process, and explicit knowledge can be transformed into tacit knowledge through the internalization process (Nonaka and Takeuchi, 1995; Nonaka and Konno, 1998). Although there are no metrics to yield the value of tacit and explicit knowledge of a given individual, we may write - using the metaphor of (1) – the following relation:

$$K = KT + KE \quad (2)$$

where: K – total knowledge; KT – tacit knowledge, and KE – explicit knowledge. Since there is no law of conservation for the knowledge field, the externalization and internalization processes are not bounded by precise relationships or metrics.

2.3. Cognitive and emotional knowledge as mechanical and thermal energy

Knowledge as energy is a challenging metaphor since we may use the fundamental concepts of thermodynamics. As a science, *thermodynamics* is concerned with the generation, transport, and dissipation of heat as a form of energy. That means also the transformation process of mechanical work into heat, and of variation of heat into mechanical work in complex systems. The general equation of these transformations can be written as follows:

$$\Delta E = W + Q \qquad (3)$$

where: ΔE – energy variation from an initial state to a final state; W – mechanical work performed by the system, and Q – heat input to the system. By analogy, we may write for the target domain:

$$\Delta K = KW + KQ \quad (4)$$

where: ΔK – knowledge variation; KW – cognitive work, and KQ – emotional heat. This relation is strictly qualitative and it introduces a difference between a cognitive process and an emotional one. By *cognitive work* we may refer to any knowledge processing event which is capable of generating action at individual or organizational level. In the field theory, any non-uniform distribution in time or space generates forces, and any variation of these forces generates fluxes which tend to produce uniformity. This is true for the knowledge field as well, and we may coin the concept of *cognitive work* as a result of variation of cognitive fluxes at the individual level or organizational level. A cognitive work is actually any flux which may generate, or which can be generated by a knowledge field variation. It is a step further from the concept of *working knowledge* (Davenport and Prusak, 2000). By *emotional heat* we may consider the emotional flux which has been induced or produced as a result of a knowledge field variation. Let us consider that we are waiting for the final result of a job interview. When it is communicated to us, we have a variation in our knowledge level, and we perform a cognitive work in interpreting this result. In the same time, an emotional flux is generated according to our expectation level: if we get the wanted job we are happy, if not, we are unhappy. Like mechanical energy, the cognitive work has an extensive dimension which eventually can be measured. Like thermal energy, the emotional heat has both extensive and intensive dimensions. In this case, the extensive dimension refers to quantity of heat expressed in Joule, and the intensive dimension refers to temperature expressed in degrees Celsius or Fahrenheit. Although we cannot measure now the intensity of a certain emotion, we can differentiate emotions based on their intensities, which means we can perform a relative evaluation of them. Introducing emotions into the knowledge metaphorical analysis it is in concordance to the Japanese view of oneness of body and mind (Nonaka and Takeuchi, 1995; Nonaka and Konno, 1998).

The second law of thermodynamics has many formulations and interpretations. However, the kernel of this law is that heat can flow by its nature from a body with a higher temperature, toward a body with a lower temperature. These two bodies can be in direct contact, or not. The reverse process can be done only by performing mechanical work. Using our metaphor, we may say that in the target domain knowledge can be transferred only from a person having a higher knowing level toward a person with a lower knowing level. The reverse process can be done only by performing some intellectual work. This idea can be further developed by using similarities between the Carnot cycle used in thermodynamics and the SECI cycle used in knowledge management. In knowledge transfer and sharing we may include both tacit and explicit knowledge. In knowledge intensive organizations, knowledge sharing is a core competency. People need to actively share and discuss their practice which is generating tacit knowledge (Debowski, 2006). "*While knowledge is often thought to be the property of individuals, a great deal of knowledge is both produced and held collectively. Such knowledge is readily generated when people work together in the tightly knit groups known as communities of practice*" (Brown and Duguid, 1998, p.91).

2.4. Knowledge entropy

The concept of *entropy* has been defined for the first time by R.J.E. Clausius in 1865, in relation with the second law of thermodynamics. Clausius' definition of entropy change could be expressed verbally as being the amount of energy dispersed reversibly at a specific temperature T. From a statistical viewpoint, the entropy is the degree of disorder or chaos that exists or is created, a

connection that has been revealed by investigations of Boltzmann and Gibbs in statistical physics. Entropy can be express as (Schroedinger, 1967):

$$\text{Entropy} = k \log D \qquad (5)$$

where *k* is the so-called Boltzmann constant, and D is a quantitative measure of disorder. Also, D can be interpreted as a probability of a macrostate of a given system, produced by its chaotic microstates. Transitions from less probable to more probable macrostates and towards equilibrium all increase entropy and consume exergy, the work potential of the given system. In the source domain of energy, entropy can be interpreted also as a measure of energy distribution and the capacity of the energy field to do useful work. The higher the entropy, the less value of the energy field (Handscombe and Patterson, 2004). In the target domain of knowledge, entropy can measure the distribution of knowledge field at the organizational level. A highly structured and non-uniform knowledge field has a low entropy value. This is a typical situation in the old view of the industrial management, where the management hierarchy is highly vertically structured and top-down knowledge flow is very well controlled (Robbins and DeCenzo, 2005). In the new knowledge creating companies, the knowledge field is less structured due to a flat management hierarchy and an intensive knowledge transfer on both vertical and horizontal directions takes place "*Hierarchies are very good at aggregating effort, at coordinating the activities of many people with widely varying roles. But they're not very good at mobilizing effort, at inspiring people to go above and beyond. When it comes to mobilizing human capabilities, communities outperform bureaucracies*" (Hamel and Breen, 2007, 62). Thus, entropy can be in the target domain an important indicator to describe organizations and their management performance. For instance, the entropy of a platoon of soldiers is very low because they are highly constrained by regulations to execute the top-down orders. By contrast, the entropy of a creative company with a lax lattice management is high since knowledge is flowing in all directions trying to level up the organizational knowledge field. It is interesting to conclude that management is by its nature *anti-entropic*, since it implies order and well defined knowledge clusters associated to well defined organizational structures. Knowledge entropy is reduced by performing cognitive work in designing these organizational structures and all internal regulations for their functioning. The final result is a perfect mechanical organization operating by bureaucratic procedures. It is a very stiff organization with a low innovation level and a low adaptive capacity. The new types of organizations are more flexible, with less structured managerial hierarchies, and higher level of innovation (Leonard-Barton, 1995; Christensen, 2003). That means a higher level of knowledge entropy. The future of management is the *entropic management*, which means a substantial change in the organizational structures and dynamics.

2.5. Synergy and syntropy

One of the most important problems of any organization is to integrate individual knowledge and individual intelligence of all employees in order to yield organizational knowledge and organizational intelligence. An organization characterized by a high density of individual knowledge and intelligence is not necessarily an intelligent organization. However, it could be if there are some organizational integrators able to create a knowledge field at the organizational level in such a way that the organizational entropy increases in a natural way. For example, universities are by their nature organizations based on learning. They deliver knowledge to the students through teaching processes. Students acquire knowledge through learning processes, from their professors and from other different knowledge resources. Since *learning* is a fundamental process within any university, we are tempted to say universities are also learning organizations. However, this might be a major error due to the learning paradox (Bratianu, 2007b): "*Although a university is an organization based on learning processes, it is not necessarily a learning organization*". A university can become a learning organization if and only if there is at least a strong integrator to assure the transition from individual learning to team and organizational learning.

In order to aggregate individual knowledge and intelligence from all the employees of a given organization one needs specific mechanisms, for creation synergies. Albrecht explains the synergy generation by coining the concept of *syntropy* (Albrecht, 2003, p.42): "*We can define syntropy as the coming together of people, ideas, resources, systems, and leadership in such a way as to fully capitalize on the possibilities of each*". While entropy measures the energy degradation in a natural system through increasing disorder, syntropy would denote the upgrading of organizational energy, knowledge and intelligence through increasing alignment, or integration of all resources and

capabilities an organization may have. The concept of *synergy* belongs to the source domain of energy, while the concept of *syntropy* belongs to the target domain of knowledge. It is an interesting semantic extension of our working metaphor, since synergy can be generated only in a system due to the property of nonlinear interdependence of constitutive elements. By similarity, syntropy reflects the integration process within a given organization. It is a direct result of organizational integrators on the generation and development of intellectual capital. According to Bratianu et al. "*An integrator is a powerful field of forces capable of combining two or more elements into a new entity, based on interdependence and synergy. These elements may have a physical or virtual nature, and they must posses the capacity of interacting in a controlled way*" (Bratianu, Jianu and Vasilache, 2007). The interdependence property is necessary for combining all elements into a system. The synergy property makes it possible to generate an extra energy or power from the working system. It makes the difference between a linear system and a nonlinear one. In the case of a linear system the output is obtained through a summation process of the individual outputs. In the case of a nonlinear system the output is larger than the sum of all individual outputs.

3. Characteristics of the source domain not used by metaphor

Energy is a very powerful concept reflecting one of the essential aspects of the universe. It is a generic concept which is able to describe the whole spectrum of motions from nanoworlds to macroworlds and the whole universe. It is applicable to both living and non-living organisms and systems, or bodies. The most important characteristic of energy is its *conservation property*, which states that energy cannot be created, and cannot be destroyed. It only can be transformed from one form to another according to physics laws. Knowledge is also a universal concept and covers many aspects of life. However, the conservation law cannot be applied to the knowledge field (figure 2). Knowledge can be created and it can be destroyed. It can be transformed from tacit to explicit, but there is no strict quantitative equivalence between the two forms.

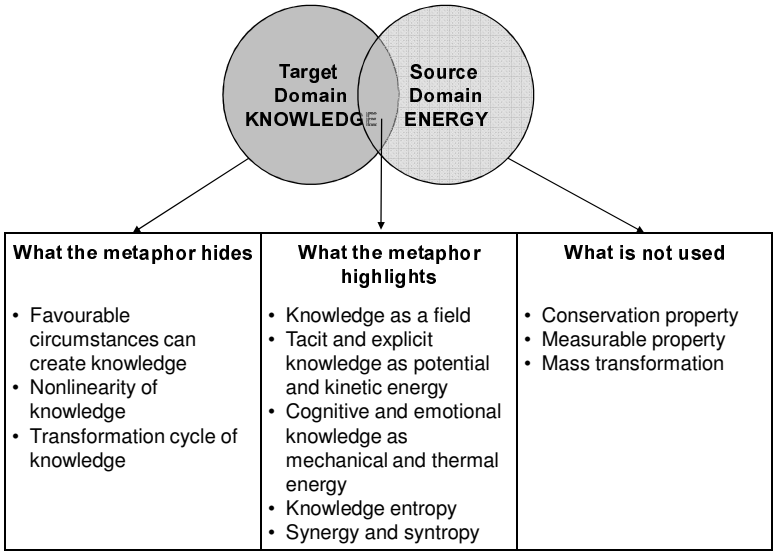

Figure 2: Highlights of the metaphorical analysis

Another characteristic of energy which cannot be used by metaphor is its *measurable property*. Energy, regardless of its form of manifestation, can be measured accurately. Energy is linear and thus the total energy of any arbitrary sum of components can be obtained using an addition operation. Knowledge is intangible and highly nonlinear. There is no measurable property defined so far, and as a consequence no universal metric developed.

According to the Einstein's famous formula, energy can be obtained at nuclear level by *mass transformation*. This property from the source domain cannot be projected onto the target domain since knowledge cannot be obtained through a mass transformation. It might be of interest to study the transformation of energy into knowledge, but that is another research topic for another day.

4. Characteristics of the target domain not covered by the source domain

Knowledge can be created at both individual and organizational levels, and Japanese companies developed specific methods to use this intrinsic characteristic. Nonaka devoted much of his research to knowledge creation in the Japanese companies and in developing a general theory based on the concept of *Ba* (Nonaka and Takeuchi, 1995; Nonaka and Konno, 1998; Krogh, Ichijo and Nonaka, 2000). In his view, "*Ba can be thought of as a shared space for emerging relationships. This space can be physical (e.g., office, dispersed business space), virtual (e.g., e-mail, teleconference), mental (e.g., shared experiences, ideas, ideals), or any combination of them. What differentiates ba from ordinary human interaction is the concept of knowledge creation. Ba provides a platform for advancing individual and/or collective knowledge*" (Nonaka and Konno, 1998, p.40). What we have not explored in this paper is the idea of how the creation of certain favourable circumstances can create energy. It would be interesting to see what we can learn from these circumstances in the source domain of energy about the target domain of knowledge. Another important characteristic of knowledge which cannot be covered by this metaphor is its strong *nonlinearity*. Due to this intrinsic property knowledge quantities cannot be obtained using the addition mathematical operation. Knowledge processing has different rules, many of them undiscovered at present time. Finally, we would like to say that the transformation cycle of knowledge according to Nonaka's theory – socialization, externalization, combination and internationalization – is far from being covered by the Carnot thermodynamic cycle.

5. Conclusions

Metaphorical analysis is a very useful way of developing new concepts and theories, by using a source domain with well known concepts. Our research presented in this paper is concerned with choosing the energy metaphor for knowledge. Thus, the source domain is energy and the target domain is knowledge. Among the most important similarities we found are the following: energy and knowledge can be considered as dynamic fields; potential energy and kinetic energy are forms of mechanical energy which can be associated to tacit and explicit knowledge, as forms of individual and organizational knowledge; energy correlation with work and heat through the second law of thermodynamics can be paralleled by knowledge correlation with the cognitive work and emotional states; entropy can be used successfully in the knowledge field with new interpretations; synergy from the source domain can be projected into syntropy from the target domain.

There are also some characteristics in the source domain which cannot be translated into the target domain: the linearity property of energy; the measurable property of energy, and the conservation law. In the target domain remain uncovered: the nonlinearity property, the creation possibility of knowledge and the sharing process, which cannot be constrained by any conservation law.

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