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Notes on Knowledge, Systems, Language and Scientific Reasoning

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Notes on Knowledge, Systems, Language and Scientific Reasoning

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ABSTRACT

In questo studio sono presentati alcuni primi elementi di metodologia dell'osservazione scientifica ed operativa che l'economista aziendale e l'operatore aziendale devono possedere per rendere formalmente efficienti ed efficaci le loro analisi teoriche e il loro operare. Si considera l'ipotesi che l'attività osservativa proceda per gradi da elementi semplici – quali la percezione e la descrizione degli oggetti – ad attività osservative evolute, quali l'analogia – che comporta la definizione dei concetti – e l'astrazione generalizzante, che consente di pervenire alle leggi ed alle teorie scientifiche tramite le quali tentare spiegazioni della realtà. L'attività dell'uomo si sviluppa in ambienti e comunità sociali nelle quali si attua la trasmissione dei contenuti di pensiero tramite i linguaggi, dei quali si considerano le funzioni e le forme di impiego. Il lavoro si conclude con alcune considerazioni sul problema della conoscenza scientifica e sull'impiego delle argomentazioni scientifiche e delle spiegazioni.

This study presents several initial elements of the methodology of scientific and operational observation that business economists and company employees must employ to make their theoretical analyses and work efficient and effective. The assumption is that observed activities gradually move from simple elements – such as the perception and description of objects – to more complex observational activities, such as analogy, which entail the definition of concepts, and generalizing abstraction, which leads us to establish the scientific laws and theories through which we attempt to explain reality. Man's activities unfold in social environments and communities in which thought content is passed on through languages, whose function and forms of use will be considered. The paper ends with some considerations about the problem of scientific knowledge and the use of scientific reasoning and explanations.

Keywords: objects of observation, observational dimensions, description, definition, classification, models, structures, systems, scientific laws, theories, explanation and prediction, Systems Thinking, languages, communication, logic and argumentation, fallacies

1 – Introduction. Scientific and Operational *"Observation"*

Without referring to the vast bibliography on philosophy, metaphysics, logic, physics, sociology, and psychology that deal with the idea of "reality", the present study will begin by defining the term "unique individual reality as the system of "perceptions" by a given subject (perceiver) during a given time interval. The breadth of the content of this individual reality depends on the state of the organs of perception, the perceived instruments at hand, the so-called "culture" of the perceiving subject, his or her objectives, and so on. By extension, the term "unique group reality" can be used to indicate the system of unique realities of a group of similar perceiver/subjects who, being capable of "communicating" through appropriate "models", can exchange the content of their individual realities. Going further, the term "general reality" can be used to indicate the system of unique group realities of all the possible groups of perceivers/subjects – who can communicate with each other – over a specific time interval. This "general reality" is impersonal and objective and represents the broadest system of common knowledge of the largest group imaginable. Henceforth, we shall use the term "*reality*" to indicate the so-called objective reality, assuming that this can be deduced from a given "system" of specific realities (individual or group).

According to a quote by Paul Watzlawick, reality is an interpersonal convention: what appears real is defined as such by a sufficiently large number of people. The individual reality, which is not transmitted and shared, cannot be verified, thus remaining in the subjective sphere:

The belief that one's own view of reality is the only reality is the most dangerous of all delusions (Watzlawick, 1976, p. XIII).

The distinction between subjective and objective 'reality' is one of the basic themes of the constructivist epistemological view. Heinz von Foerster, an advocate of this view, distinguishes between two processes for observing 'reality': that which excludes the observer from the observative-cognitive process and that which includes him as an essential part of the observation. In the first case, the observation leads to a 'reality' made up of 'objects', while in the second it leads to a reality composed of 'stable symbols' of behavior (von Foerster, 1987, pp. 179-180). The present study presents a cognitive constructivist syntax.

Due to the nature of the cognitive process and the function of the linguistic interactions, we cannot say anything about that which is independent of us and with which we cannot interact; [...] it follows that reality as a universe of independent entities about which we can talk is, necessarily, a fiction of the purely descriptive domain, and that we should in fact apply the notion of reality to this very domain of descriptions in which we, the describing system, interact with our descriptions as if with independent entities (Maturana and Varela, 1980, pp. 52-53).

Three typical types of behavior or attitudes can be manifested with respect to reality:

1) *contemplative*, to achieve *ecstatic*, *esthetic* or *expressive* goals, which are notably subjective ("what a beautiful flower..."; "what strange mold in that bowl...");

2) *cognitive*: here *cognitive* goals are sought which, in turn, can be divided into:

2.1) *scientific* cognitive goals aim at knowledge for explanatory ends: "knowing *what*, to understand *why*" ("it's a rose... of the family..., it usually grows in temperate climates, since to grow it needs...calories; its color can be...", etc.; it's an unknown type of mold with the following structure and incubation period..., growth rate of..., it can destroy the following bacteria..., in (amount of time) ...");

2.2) *operational* cognitive goals to gain knowledge in order to act: that is, "knowing what, in order to understand *how*" ("how can I pick the rose without pricking myself?"; "how can I separate the mold from the other cultures without destroying it?");

2.3) *pragmatic*, or *operational*, with the immediate objective of intervening *on the* (in the) reality to modify some of its aspects to achieve various types of objectives (pick the rose, sterilize the bowls).

Henceforth, "*observation*, scientific or operational" – or simply "observation" – will refer to activities undertaken by a subject in the context of a cognitive, scientific or operational attitude or behavior toward reality, even one specified ad hoc, in order to construct significant models of this reality. *Observation* is indispensable for the knowledge that is the basis for evaluating, deciding and implementing the actions decided on, and for controlling their effects, as shown in **Figure 1**.

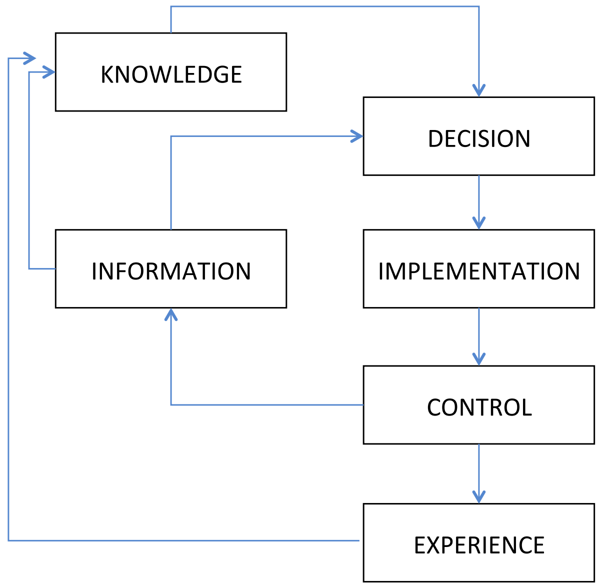

Figure 1 – The role of *observation*

The main objective of this conceptual paper is to point out several methodological elements useful in outlining a simple *Theory of Scientific Observation* that, as it is formalized, can be used to verify the coherence and completeness of any type of observation. The theory presented in this study was also developed in Piero Mella, 1977, 1982, 1992 and in part, and for other purposes, in Piero Mella, 2014a, Chapter 9.

2 – "Objects" of Observation and Observational "Dimensions"

Following the *constructivist* (*epistemological*) *view* (for example, George Kelly, 1955; Jean Piaget, 1937; Paul Watzlawick, 1976; Humberto Maturana and Francisco Varela, 1980, 1992; Kurt Lewin, 1935, 1948; Heinz von Foerster, 1984, 1990; 2003; Niklas Luhmann, 1988, 1997; Daniel Lee, 2000); Gregory Bateson, 2000, 2002: Silvio Ceccato, 1969, 1974; Ludwig Wittgenstein, 1921,_and many others), "reality" is composed of a variety of stimuli that arrive under the form of atomic differences through *sense* organs (sight, hearing, touch, etc.) and general physical sensibility (position of the limbs, sensations in the internal organs, etc.). Such stimuli are continually selected, ordered and classified by our mind.

In *Mind and nature: A necessary unity*, Gregory Bateson proposes an epistemological theory of knowledge based on the simple model of "mind" (which I developed in Mella, 2014a, Ch. 9) as the capacity of a cognitive system, or individual, to observe reality and form a representation (map) of the world (territory) through the perception and ordering, even at successive levels, of differences.

1. Mind is an aggregate of interacting parts or components. 2. The interaction between parts of mind is triggered by difference and difference is a non-substantial phenomenon not located in space or time. 3. Mental process requires collateral energy. 4. Mental process requires circular (or

more complex) chains of determination. 5. In mental process the effects of difference are to be regarded as transforms (that is, coded versions) of the difference which preceded them. 6. The description and classification of these processes of transformation discloses a hierarchy of logical types immanent in the phenomena (Bateson 2002, p. 92).

Bateson believes *differences* are not substantial phenomena since they do not result from a comparison involving the values of variables the cognitive subject is capable of (must be capable of) determining and comparing in order to produce new differences for subsequent comparison (Bateson 1979, p. 122). Assuming a typical constructivist view, Gregory Bateson – by adopting a simple metaphor – distinguishes between knowledge and what is known, comparing knowledge to a "map", what is known to a "territory": "The map is not the territory, and the name is not the thing named" (Bateson 1979, p. 30; see also Mella 2012, section 2.12).

The map – that is, knowledge – is formed by taking account of the differences the observer perceives in the territory represented; these differences and their transforms are "elementary ideas … and these differences are themselves to be differentiated" (Bateson 2000, p. 463). Bateson believes differences are not substantial phenomena since they do not result from a comparison involving the values of variables the cognitive subject is capable of (must be capable of) determining and comparing in order to produce new differences for subsequent comparison.

I have said that what gets from territory to map is transforms of differences and that these (somehow selected) differences are elementary ideas. But there are differences between differences. Every effective difference denotes a demarcation, a line of classification, and all classifications are hierarchic. In other words, differences are themselves to be differentiated and classified. In this context I will only touch lightly on the matter of classes of difference, because to carry the matter further would land us in the problems of Principia Mathematica (Bateson 1972, pp. 463-464).

Among the various basic perceptive operations of which we are aware – since we are used to carrying them out beginning in our infant learning phase – two are particularly important, since they are integral to knowledge:

a) forming *objects of observation;*
b) identifying *observational dimensions.*

We are used to identifying "objects" in "reality" by systematizing perceptions which, no matter how diverse, we deem correlated and "derived" from the same "entity". This thought activity occurs constantly, leading us to conceive of objects even when a careful analysis indicates there is no concrete or autonomous entity. When we "observe" a pen, a house, a piece of candy, a person, we do not doubt we are observing an "object" – possessing color, weight, hardness, taste, etc. – even if we in fact perceive "sensorial differences" – visual, tactile, auditory stimuli, etc. – that our mind associates in a unitary system: "the pen", "the house", "the candy", "the person". Moreover, we are used to considering as "objects" a window, a hand, a circle drawn on a blackboard, a road, even if it is difficult to conceive of the "weight" of a window, the "height" of a hand, the "scent" of a circle, or the "taste" of a road.

The human mind thus carries out a "constitutive" function that manifests itself in the ability to order the perception of differences from various organs into various types and sizes of "objects", which are interrelated and form a "universe".

We can formally derive the following definition: the mind *constitutes* an "object of observation" when it *jointly considers* (during a given time interval) "sensorial differences", even through successive approximations, so as to form a unitary whole. The *constitution* of the objects of observation usually represents an elementary activity carried out unconsciously by the mind. Based on this definition, we can symbolize an object as follows:

$$\{ d^1(O_h) \& \ldots \& d^m(O_h) \& \ldots \& d^M(O_h) \} \rightarrow O_h \qquad [0.1]$$

The fundamental relation [0.1] is to be read as follows: if I jointly perceive ("&" means logical conjunction) the M perceptions d^m, then they can refer to an object resulting from the constitutive activity; that is:

IF "I perceive"

$\{d^1(O_h) \& \ldots \& d^m(O_h) \& \ldots \& d^M(O_h)\}$

THEN "I observe" O_h [0.2]

In effect, our mind elaborates [0.1] so quickly and immediately that our mental universe is a "world of things" and a "relational" world: perceptions are not isolated but constantly classified as "objects" (improperly as "things"), which in turn are ordered in different ways. When we observe "the pen on the desk", "the neighbor's house", "the just-bought candy", "our aunt", *we have no doubt* we are *observing* an *object* – possessing color, weight, hardness, flavor – even if we in fact perceive "sensorial differences", and visual, tactile, auditory differences, etc., which our mind correlates in a unitary system: "the pen", "the house", "the candy", and "the person" observed (I have written "the pen on the desk" in quotation marks to indicate reference to a specific observed object: a particular pen. The need to use language to describe the observational operations also entails distinguishing the terms to indicate observed objects and concepts; see Section 22). Nevertheless, we are used to also considering as *objects* a window, the length of a hand, the flavor of a street or the color of an intersection. Even the language that becomes familiar to us from childhood is a "relational" language and one of "things"; the habit of using it to efficiently communicate our perceptions makes us lose awareness of the integral activity of our minds.

However, when our mind "becomes used to" constituting objects, so that out mental universe appears as a "world of things", it becomes natural to invert the reasoning in [0.2] (which indicates that every object derives from the coordination of perceptions through the constitutive activity of the mind) and assume that, vice-versa, perceptions appear coordinated in that they *derive, originate,* from the objects and are symptoms, or signs, of their presence. Under this hypothesis, [0.2] should be rewritten as follows:

IF "I observe"

O_h

THEN "I perceive"

$\{d^1(O_h) \& \ldots \& d^m(O_h) \& \ldots \& d^M(O_h)\}$ [0.3];

that is to say: if I observe Oh, then the perceptions must derive from this and thus be joined. The two representations are basically different; [0.2] represents the objects as they are formed *unconsciously* (typically in infancy); different perceptions constitute the object, but the mind is not conscious of such operations. [0.3] represents the objects as they are considered at the *conscious* level. The mind, after constituting the objects at the unconscious level, observes the perceptions that characterize them.

To become conscious of our tendency to "think in terms of objects" even when our mind receives simple perceptions, we imagine being in a dark room with unknown objects. We move around without being able to see and perceive both tactile sensations, represented by collisions and other contact, and acoustic and olfactory perceptions correlated with the preceding ones. How does our mind behave? It is "natural" to try and identify the "objects" that might have caused those perceptions; we can thus "assume" there is a sharp-cornered piece of furniture, a glass that has fallen and broken, a soft cushion, a carpet, etc. Under this hypothesis, [0.3] should more correctly be written as follows:

IF "I assume"

O_h

THEN "I perceive"

$$\{d^1(O_h) \& \ldots \& d^m(O_h) \& \ldots \& d^M(O_h)\} \quad [0.4]$$

From this it follows that in a "world of things" the observation of objects always implies their "recognition" in a "catalogue" of already-defined objects. [0.2] provides the representation of the objects we can refer to as *gnoseological, constitutive*; [0.3] and [0.4] offer a representation of the objects we can call *epistemological, observative*.

Generalizing the above considerations, in our "world of things", we realize that the set of observable objects includes not only entities we consider concrete "things"; it can also include events, operations, actions, facts and, in general, dynamic phenomena: that is, the results of perceptions. We define objects of observation (or observed objects) as any "entity", simple or composite, that is subject to scientific or operational investigation. We can agree to include among the objects of observation not only those contained in a given reality – which shall be termed "real" – but also those "imaginary" ones (in the abstract sense) that derive from mental activity consisting in:

a. attributing to certain objects – using new terms or based on unusual relations – "states" not found in them but deriving instead from the observation of other objects (for example, associating a color to an electron, imagining a three-headed dog, a unicorn, a winged horse, a flying carpet);

b. using our imagination to create new objects, by associating observable and associable "states" to real objects (Dante's Paradise, Pinocchio, "the Gods");

c. forming abstract imaginary objects for various observative needs; some of the objects which scientific observation has not yet demonstrated are 'real', but whose existence they have not been able to refute either, can be termed 'hypothetical' (for example, "the Angels", antimatter, the Big-Bang, the "strings" and "branes" used to theorize about the nature of the universe, the soul, the life force).

"Imaginary" objects, since they are not "observable" though they are expressible, can be referred to as "nominal". Some imaginary objects, which scientific observation has not yet demonstrated are "real", but neither has disproved this, can be referred to as "hypothetical" ("the Angels", anti-matter, the Big-Bang).

The *second* typical element in our mental activity consists in becoming aware that the observed "objects" are characterized by "states" that allow for comparison, arrangement and classification. The characteristics based on which certain types of object can be compared and classified are "states" or "values" taken on by a specific *observational dimension*: weight, color, taste, height, function, etc. Therefore, the "dimensions" can be thought of as *generalized modes* of *perception* (weight, color, etc.) or of *association* (name, relative position, etc.) of sensible or imaginary differences deemed to be of the same type even though appearing to the observer in different objects. More simply, the *dimensions*, taking on different features in the "objects" in question, can be thought of as *variables* our mind can imagine and/or perceive that take on different "states", or "values", in the various objects of observation.

Therefore, the "dimensions" are not only *spatial* or *ponderable* but can be of the most variable types – name, brand, age, date and place of birth, coefficient of refraction, spin, material of composition, color, shape, function, mode of use, placement, lay-out, etc. – since, similar to the objects, they are posited by the observer through a mental activity involving the perception and generalization of differences among differences: states of the observed objects deemed similar lead to the generalization of "dimension".

Obviously, not all the objects of observation can be characterized by the same dimensions. While "color" and "weight" characterize automobiles as well as the obelisk in St. Peter's Square in Rome, it makes no sense to also attribute such dimensions to the lunar eclipse on June 18, 1873, or to the Great Bear constellation. Moreover, while the dimension "parents' names" can be observed for many biological beings, there is no sense in using it to refer to the shoes we wear, just as it makes no sense attributing the dimension "number of red blood cells per unit of blood" to plants. Therefore, when we observe *objects* we must refer to a given set of *dimensions* held to be of interest.

3 – Observative, Observable and Observed Universes

The observation of reality thus proceeds by means of the *establishment* of *objects* and *dimensions* that allow us to characterize and compare objects. By considering together the notions of *object* and *dimension*, it is possible to introduce that of "observative universe". Let us suppose we have identified, or predetermined, N *dimensions* through which to observe – distinguish and order – the objects of a specified "reality". These dimensions represent an *observative universe*, and we can write:

$$U(N) = [D_1, D_2, \dots, D_n, \dots, D_N] \qquad [1]$$

The dimensions that define the observative universe can be referred to as *observative coordinates*, since they allow us to distinguish and order the *objects* based on the *states* of those dimensions. The size of a given *observative universe* depends on many factors: the objectives of observation, the available tools of observation, the nature of the objects to observe, and, in general, the personal equation of the observer, that is, all the personal (and social) characteristics that can influence the observation.

If ΔD_n indicates the observable *field* of dimension D_n (for example, we do not perceive ultrasounds, which are outside the observable field of audible sound frequencies), then the vector:

$$UO(N) = [D_n, \Delta D_N] \qquad n = 1, \dots, N \qquad [2]$$

is defined as the *observable universe* and includes the set of objects that, based on the available tools of perception, can have a *state* belonging to any of the dimensions in [2]

Different sciences can refer to the same *objects of observation*, but the scientific disciplines differ in that they proceed with their observations in the context of different *observative* and *observable universes*. By varying these, the set of observed objects – that is, the *observed universe* – also varies. Atomic physics and molecular chemistry, on the one hand, economics, political science and sociology on the other, probably consider the same objects but observe different dimensions of them. The observative universe we can investigate as men, without the aid of scientific instruments, does not include the objects that appear to the astrophysicist, who can widen the observative universe, and thus the observable universe, thanks to radio telescopes that reveal dimensions precluded from normal perception without the aid of instruments.

Note: Since the various sciences consider different observative universes, they produce theories and laws that can provide valid "explanations" and "predictions" (see section 21) for the separate observative universes. The problem arises of the *unification of the sciences*; that is, whether it is possible to form a single observative universe for all the sciences, thereby reducing the observative universes to the minimum amount, making it possible to identify valid theories and laws to solve any scientific problem.

4 – The Technical Descriptions

The first step in acquiring knowledge is the "description" of an object. Let us consider an object A (for simplicity's sake, "A" can indicate a conventional state of the variable "name" of the object). After a little thought, we immediately realize that when we observe A, we in fact perceive the "states" of some dimension that characterizes that object. We can distinguish a book lying on a desk because we perceive different colors on the object "book", which is distinct from the object "desk". We can perceive the object "pane of glass" not because we can distinguish its color or weight, but because we perceive its dimensional states, which are revealed through tactile sensations such as the feeling of fresh air and, above all, through its impenetrability. We can distinguish the object "hand" by the difference in how it functions compared to the other parts of our body; and so on.

It is easy to see that object A can be distinguished from B only if at least one of its dimensions has a different state. If there are 10 books in the bookcase, I can distinguish these by, for example, the dimensions "height", "thickness" and "cover color". If two books have the same height, thickness and color, I can distinguish them by the dimension "author's name". If the state of this dimension is the same for several books, I can attempt to distinguish them by the dimension "title", and so on.

Generalizing the above considerations, any "object of observation" can be described by the "states" of the dimensions that characterize it in the predetermined *observative universe* [1]. If D_n indicates the n-th dimension the observer is considering in $U(N)$, and $d_n(A)$ the state that dimension takes on in object A, then the "technical description of A" is the vector:

$$[desA] = [d_1(A), ..., d_n(A),..., d_N(A)] \qquad [3]$$

The *technical description* of an object of observation thus represents the *specification* of the *state* of the dimensions characterizing that object in the predetermined observative universe [1]. The *description* is "*technical*" since, for the moment, we are assuming we do not have any language to translate it into a linguistic description, as indicated in section 21). The *technical description* of an object (material or immaterial; individual, group or system; phenomenon, event, act, operation, process, etc.) or of a given part of reality is conceived of, in the broadest sense, as the first fundamental *unit of observation* by a cognitive agent; better yet, it represents the primary source of knowledge, as Emmanuel Kant observed when stating that all the ideas and concepts possessed by an individual are nothing other than his own creations. External things are only occasions that cause the mind to operate to produce descriptions, ideas and concepts (Kant, 1781).

We can make the notion of *technical description* even simpler and more general: a *technical description* is nothing other than a "point" in the specified *observative universe*, formed by assigning a "state" (a "value") to the N "observative coordinates" in [1]. It immediately follows from the above considerations that two objects, A and B, can be considered "equal" only if [des A] = [des B], if obtained from the same *observative universe*; that is, for each of the N dimensions $d_n(A) = d_n(B)$. The notion of "equality" is clearly *relative* since it depends on the *obsevative universe* considered, on the objectives, and on the observational instruments. We could presumably state that two coins are equal that have the same "face value" and same shape, weight, diameter, thickness, and are made of the same metal. If we extend the observative universe to include the dimensions "year coined", "owner", "number of component molecules", "number of surface micrometric pores", etc., it would be difficult to observe the "equality" of the two objects.

5 – Types of Dimensions

The dimensions that make up a given observative universe can be of several types and natures; their number depends to a large extent on the objectives of the observer and the instruments available to him. An initial important classification of the dimensions is that which distinguishes them, based on the relations they have with the objects of observation, into:

a1) *ascertainable* (or observative) *dimensions*: these are directly observable in the objects of observation without need for the observer to undertake any evident steps, as occurs instead for "weight", "taste", "color", and spatial dimensions;

a2) *associated* (or associative) *dimensions*: these are determined by the observer for fact-finding and operational aims; for example, "name", "specific weight", "value", "prevalent color", and "tax code number".

A second classification, based on the various possibilities of comparing the objects of observation, divides the dimensions into:

b1) *quantitative dimensions*: these are dimensions for which it is possible to compare the objects of observation. More specifically, if $d_n(A)$ and $d_n(B)$ are the states dimension D_n can take on in objects A and B, then D_n is a *quantitative* dimension if A and B can be compared using the same terms defined in the *arithmetic relation* below, which indicates the difference:

$$d_n(A) - d_n(B) = s(A\text{-}B)$$

and/or in the *geometric relation* expressed by the quotient:

$$d_n(A)/d_n(B) = q(A/B)$$

The value s(A-B) signifies "distance" (or "space") between A and B relative to the dimension D_n; the quantitative dimensions are for this reason called *extensive*. The value q(A/B) signifies "quantitative relation" between two objects; in other words, D_n is quantitative if it is important to compare the various objects in relation to this dimension to affirm that A is greater than B in s(A-B) or A is q(A/B) times B (obviously, other relations are possible in which $d_n(A)$ and $d_n(B)$ are inverted). To specify s(A-B) and/or q(A/B), the dimensional states $d_n(A)$ and $d_n(B)$ must correspond to *cardinal* numbers; or, more precisely, *cardinal scale* numbers;

b2) *qualitative dimensions:* for these dimensions it makes no sense to compare the objects of observations since: (i) the states for these dimensions cannot be numerically expressed ("it tastes like strawberry", "it's green, white and red", etc.); (ii) at most, they can be represented by numbers indicating an order: that is, *ordinal* or "ordinal scale" numbers ("I live in via Garibaldi 125", "the telephone number is 123456", "the registration number is P 6543Q", etc.); (iii) they can be represented by numbers (called *nominal*, "nominal scale" or even "conventional") that function as a "name" ("that item in the wharehouse is 127/S/34", etc.).

In addition to the usual dimensions of space, width, height, depth, volume, surface area, those of weight, temperature, speed, etc., are also quantitative. For example, we can state that a body with a temperature of 40 degrees centigrade is twice that (in terms of this dimension) of a body (everything else equal) of only 20 degrees centigrade (even if the temperatures with respect to absolute zero are 313 and 293 degrees, respectively). The dimension "maximum speed" is quantitative. If we associate with this dimension the numbers 170 km/h for car A, 150 km/h for B, and 340 km/h for C, it makes sense to say that C is twice the dimension of A with regard to speed (or, put differently, though improperly: C has a speed twice that of A; or, even more improperly: the speed of C is twice that of A); the maximum width of the dimensions and the cylinder capacity of a power unit are also quantitative.

A *qualitative* dimension is defined as "absolute" if its states cannot be re-expressed by equivalent states obtained through simple changes in the scale of determination. Again in the case of three cars: name, location, owner's name, car manufacturer's name, brand, type and color represent absolute qualitative dimensions of each car. Instead, the dimensions date of purchase, chassis number and license plate number are qualitative and ordinal.

6 – The Determination of the Dimensions

To carry out a *technical description* of objects of observation, it is necessary to specify the state of each dimension in the observative universe, whether it be an *observative* or *associative* dimension. *Determination* is defined as the operation (or procedure) through which we specify the "state" (the "terms", "boundaries") of a dimension in the most precise way possible. The determination must be:

a) *admissible*, in relation to the nature of the object of observation and the determining dimension;

b) *possible*, in relation to the available instruments, taking into account the technological level of the environment in which the observer operates;

c) *convenient,* in relation to the objectives of observation, assessing the sacrifices and advantages of greater accuracy compatible with the resource and time constraints (Beretta, 2018, p. 101).

The determination can be:

1) *quantitative,* if it allows us to characterize the dimension using *cardinal scale* numbers;

2) *qualitative,* if it specifies the dimension in non-numerical terms, or at least through *ordinal* or *nominal scale* numbers.

The dimensions for which we can make a *quantitative* determination are knows as *magnitudes*; the result of the determination represents the *quantity* of the magnitude. The dimensions that are different than the magnitudes are also known as *modalities*, and the result of the latter are referred to as *quality*.

The most common methods for *quantitative* determinations are:

a) *enumeration*;

b) *measurement;*

c) *metricization*, which is more general.

The first type of procedure is applied to composite objects made up of aggregations of elementary, discrete and independently determinable objects, groups of distinguishable elementary objects, or dimensions of objects with such characteristics. *Enumeration* consists in determining the number of elements that make up the observed object, or the dimension to be determined, by "counting", that is, through "enumeration". *Measurement* involves obtaining a *number-measure* either by constructing an effective *cardinal scale* on which to position the magnitude to be measured, referring several times to a unit of reference – which represents the scale unit – and counting the recurrences (for ex., we quantify the length of a building) or by positioning the object, with respect to the measured magnitude, on a pre-determined cardinal scale (for ex. we measure the weight of fruit we buy by placing it on a scale and reading off the resulting cardinal number). Two measures are considered *homogeneous* if they can be quantified using the same measuring procedure.

Magnitudes, quantities and *measurements* must not be confused. While a *magnitude* is a dimension that permits quantitative determination, *quantity* is the number the observer deems suitable for positioning the object on a cardinal scale. Often *quantities* can be obtained by using alternative *measuring processes* or *instruments*. A *measure* becomes a quantity only when it is "accepted" by the observer as a number suitable for positioning the object relative to a pre-determined cardinal scale. For example, "the" inflation rate in an economy is obtained from one of the possible general price indices held to be significant; "the" income of a company is identified with one of the many measures of economic results obtainable using different systems and accounting principles.

The above definitions reveal that it is not always possible to decide *a priori* whether a dimension is quantitative or qualitative, since the distinction is linked to the possibility of identifying acceptable and operational procedures for a quantitative determination. For example, the observer cannot quantify through enumeration or measurement the dimensions for the "utility" of certain goods, the "importance" of certain objectives, or the "urgency" of certain needs. While we can imagine that one good can be twice as useful as another, that one goal is twice as important as another, that one need must be satisfied twice as urgently as others, until now any measurement procedure that requires searching for a good, objective or need that can serve as a scale *unit* has been inapplicable. We only have recourse to metricization, when applicable, by assuming an ad hoc metric space.

A metric space is the name given to a set E in which, for any two of its elements x and y, there is defined a real, non-negative number, called a distance between x and y, denoted by p(x, y). At the same time, following conditions should be satisfied:
(1) $p(x, y) = 0$ if and only if $x = y$;
(2) $p(x, y) = p(y, x)$ (axiom of symmetry);
(3) for any three elements x, y and z: $p(x, y) \leq p(x, z) + p(z, y)$ (triangle axiom).
The elements of a metric space are more often called its *points*. The requirements listed above are in accord with our everyday ideas about distance. Distance is always non-negative; distance is equal to zero only between coincident points; in defining the distance p(x, y) the order of x and y is irrelevant («the distance from x to y is equal to the distance from y to x»); finally, the triangle axiom expresses the fact that, speaking figuratively, the straight line from x to y should not be longer than any other way from x to y through another point z. In particular, all these properties are characterized by distance on a plane surface in three-dimensional Euclidean space. However, in defining the general notion of a metric space, all the requirements are not deduced from any earlier established facts, but are formulated as axioms (Vulikh, 1963, pp. 71-72)

Metricization, of which enumeration and measurement are specific cases, assign a cardinal scale number to the different objects by using various procedures to verify the "congruence" of the metric numbers assigned. The two most well-known procedures are: the *Direct Comparison Procedure*, which uses recursive procedures, and the *Standard Comparison Procedure* (Mella, 2014a, Sects 4.8.8 and 4.8.9).

The first procedure is applied to the theory of decision-making and the operational search for the weighting of the objective or for the determination of a measure of the pay-off of a given set of predicted results of courses of action (Churchman and Ackoff, 1954; Churchman et al., 1957; Ackoff and Sasieni, 1968; Fishburn, 1967). This procedure derives from the same logic as that used in the formation of metric spaces and consists in carrying out reiterated comparisons among the various objects of observation whose dimensions must be metricized after assigning each of them a first-approximation measurement. These approximated measures are then subjected to a succession of adjustments so that, at the end of the process, they are consistent with the premises of the rational observation of the distances and the relationships among the objects, as discussed in section 5 above. The objects are thus inserted into a "metric space" created ad hoc.

The *Standard Gamble Method*, though capable of being generally described for the metricization of the dimensions of any species, is in fact conveniently applicable in all cases in which the observer can express preferences among the "linear combinations" of given objects relative to the measurand dimension. The procedure was proposed in this context by John von Neumann and Oskar Morgenstern, in Theory of Games and Economic Behavior (1953, p. 26 and following) based on the premise that, given three objects, A, B and C, observed in a non-quantitative dimension D (importance, urgency, etc.), the observer can first order the three objects relative to D, for example, finding that A>B>C, and, second, determine from personal choice (through some experiment) a coefficient of equivalence, "c", ranging from "0" to "1", so that B (the intermediate object) is held to be equivalent (~) to the "linear combination" of the other two: B ~ c A + (1-c) C. Once "c" has been determined, the observer can assign the following metric scale to the three objects: nA = 1, nB = "c", nC = 0 (a general axiomatization of the *Standard Gamble Method* can be found in Luce and Raiffa, 1967, in Champernowne, 1969, as well as in Blackwell and Girshich, 1954).

Since the technical description of any object of observation includes various quantitative dimensional states, we immediately realize how little sense it makes to try and determine "the magnitude" of an object in other than *relative* and *conventional* terms. "The magnitude" of an object is "one" of the magnitudes making up its dimensional vector, which is in turn obtained by "combining" in various ways quantitative dimensions held to be elementary.

While we can all agree that the "magnitude" of a solid corresponds to its volume (or perhaps to its weight or total surface area), it is more complicated determining the "magnitude of a company", which has no logical solution since there are as many magnitudes as there are quantitative dimensions associated with the company. Quantifying "the magnitude of a company" in terms of the amount of "sales revenue" (turnover, business volume), "number of employees", even "amount of equity" (or of "invested capital") means from time to time favoring "one" specific magnitude as indicative "of the magnitude" of the company.

7 – Simple Objects and Composite; Separate and Unified Objects

Though unitary, the objects of observation can be "simple" or "composite" objects. A *simple* object is one that, for an observer and/or a specific observation, is considered *unitary*; that is, not capable of being broken down into other component elementary objects having an independent significance. An object is *composite* or (*complex*) if, vice-versa, it can be divided into parts for purposes of independent observation.

Naturally, the distinction is relative. An object is never simple or composite in terms of its nature but in relation to the goals and instruments used in carrying out a given process of observation. For the business economist, the *stock* can be considered both a simple object (as an amount for calculating the leftover stock at a given moment) or a composite one, when we must determine, for example, the optimal stock or the level of supplies for each of the warehouse codes.

The objects of observation can also be divided into *separate* or *unified* objects. Formally speaking, objects A and B are separate if, *for every dimension* D_n, belonging to the *observative universe* [1], we can independently determine the states for A and B. If there is a dimension, say D_n, regarding which the state $d_n(A)$ cannot be determined separately or independently with respect to $d_n(B)$, but for which the only possible determination is for d_m(A & B), then A and B are *united* in dimension D_n, even if it is observable independently for some other dimensions.

This distinction is clear the moment we consider that we recognize both an individual as well as an arm, hand, a finger, a phalanx, a nail as objects subject to independent observation, even though a nail, phalanx, finger, hand and arm are objects that are united and not separated from the rest of the individual's body. A lathe, factory, piece of furniture, worker, a purchase are examples of separate objects. An assembly line of 200 machines operating in sync to carry out a single process is a structure of non-separated (the 200 machines) but separable objects. The transferred good and the corresponding payment in a mutual exchange and the foliage and trunk of a tree are examples of united objects, separable only by means of *simplifying abstraction*. The dimensions according to which objects are *separate* are defined as *concrete dimensions*; those for which the objects are *united* are defined as *abstract dimensions* since they cannot be determined for the individual united objects (for example, how long is a hand? Where does the object "hand" begin and end when it is united to the object "arm"?). The *abstract* dimensions can, however, equally be independently determined on condition that some *fictional hypothesis*, or *conjecture*, is introduced that allows the states that abstractly refer to the united objects to be specifically determined. The determinations that are obtained in this way are defined as *abstract* or *conjectural*.

The distinction between *concrete* and *abstract* dimensions is significant since, while the "determinations" of the former are *ascertainable* – that is, they can approximate something that is "certain" – those of the latter cannot, since they are *abstract* or *conjectural*. *Ascertainable* determinations can be further divided into *certain* ("we have issued 120 invoices to our clients"), "approximated" with an estimate, or *estimated* ("around 300,000 quintals of oil are in our tanks"), and "approximated" with a forecast, or *forecasted* ("sales next month will probably amount to 40,000 units").

The difference between certain and approximate "determinations" is connected not so much to the nature of the objects of observation and the dimensions to be determined as to the *degree of reliability* the observer has in the results from the procedures and in the instruments of determination employed.

A determination "is" certain if it is obtained through a procedure capable of producing an unequivocal result, compatible with the reliability of the available instruments: that is, where the *tolerance* is held to be zero. On the other hand, determinations that are *approximated with estimates* result from the use of procedures or instruments that provide results with a variance that is too high with respect to others and that thus cannot be deemed certain. "Abstract determinations", since they belong to dimensions of united objects, are never ascertainable: at most they can be "congruous" in relation to the results of other determinations, in light of the "fictional hypotheses" adopted.

Since in both business economics and accounting abstract determinations are frequent and of fundamental importance, it is useful to illustrate the concept more in depth with a simple example, whose absurdity immediately brings out the idea of "abstract quantity".

Assume there are two production processes, P1 and P2, and a factor F which is used jointly for the production of both. CF is the cost of F. We wish to determine the shares of q1 and q2 to attribute to CF, so that (q1 + q2) = CF, to express the economic contribution of F to P1 and P2. Clearly, we can only observe the phenomenon "contribution of F to (P1 and P2)", not the two distinct phenomena "contribution of F to P1" and "contribution of F to P2". Whatever determination that divides CF into q1 and q2 is mere conjecture based on some *fictitious hypothesis* about the nature of this contribution that established the *conventional drivers of the subdivision* of CF; q1 and q2 are conjectural or abstract quantities even if CF can be a certain quantity.

8 – The Technical Definition

The process of observation is not limited to the perception of the individual objects and to their description; the immediately subsequent step in the knowledge process consists in identifying the *similarities* and *analogies* among the different objects (Bateson 2000, pp. 463-464). We can intuitively understand that two or more objects of observation are *similar* if, first, they belong to the same *observable* universe and, second, the differences in the quantities and qualities of the individual dimensions in the *observable* universe are contained in ranges of variation defined from time to time by the observer. In fact, when we observe objects with different structures, shapes, colors and locations we can easily see these are "houses". Nevertheless, the dimension "number of floors" has a maximum quantity, above which we recognize not simple "houses" but "skyscrapers". Even the dimension "material of construction" can take on various qualities; however, it is easy to distinguish "houses" and "skyscrapers" from "sheds" and "igloos".

As was the case for the *technical description*, the introduction of symbols will enable us to unequivocally formalize the concept of *technical definition.* As usual, $d_n(A)$ and $d_n(B)$ indicate the states of dimension D_n with respect to the objects A and B. These objects are considered "similar" by an observer with reference to dimension D_n if, even though the two states have different dimensions, they both belong to the same *range of admissible variation*, which we indicate by Δd_n; that is, even though $d_n(A) \neq d_n(B)$, at the same time $d_n(A) \in \Delta d_n$ and $d_n(B) \in \Delta d_n$.

We can repeat this reasoning for each of the N dimensions that define the *observed universe*, and for each D_n determine a *range of admissible variation*, Δd_n, so that the objects whose technical description have dimensional states that fall within those ranges can be considered "similar" by a given observer. We shall define as the "technical definition" of "object O*" the vector that, along with the dimensions of the *observative universe*, also includes the *range of admissible variation* of each dimension needed for the similarity to exist for a given observer.

$$[\text{def } O^*] = [(D^*_1, \Delta d^*_1),\ldots, (D^*_n, \Delta d^*_n),\ldots, (D^*_N, \Delta d^*_N)] \quad [4]$$

The preceding defining expression now allows us to formally deduce that A and B are similar for an observer if, even though [des A] ≠ [des B], [des A] ∈ [def O*] and [des B] ∈ [def O*].

Thus, for example, all the named objects from A to F in **Figure 2** can each be considered different from the others regarding the technical descriptions obtained from the following *observative universe*.

U(7, x) = [number of sides, color of sides, length of sides, surface area, surface color, direction of highlighted vertex, position], x = A, B, ..., F.

The generalizing activity carried out by an observer might consider figures A, C and D similar; for example, since they have the same number of sides, independently of their "color", "length" and "width". Figures B, E and F could also be considered similar in terms of the number of sides. However, another observer could consider the figures with sides of a given thickness to be similar, independently of the number of sides; a third observer, on the other hand, coud consider to be similar figures with vertexes pointed North relative to the figure. In each case, the analogic activity is always subjective, since it is always a mental activity. It is necessary to clarify the meaning of object O* in the *technical definition* [3]. Formally, O* indicates the set of all objects for which there is similarity in that given *observed universe* and for a given observer; that is, the set of objects of observation whose *technical description* is included in the *technical definition* of O* provided by a given subject.

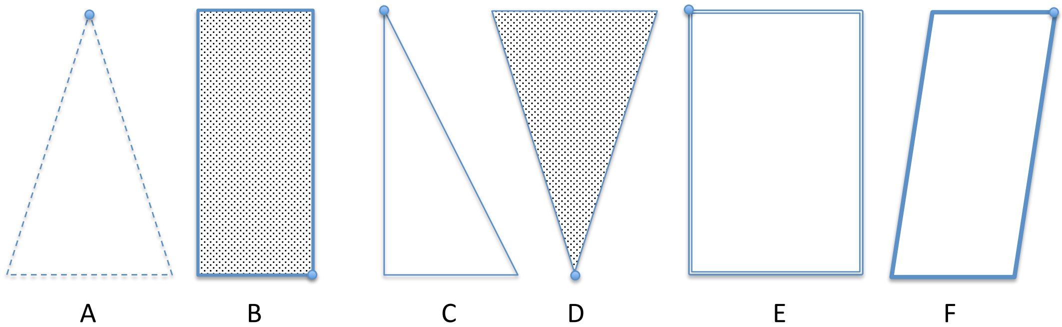

Figure 2 – Technical definition. An example (source (source: Mella, 2014a, p. 472)

In terms of observative operations, O* corresponds to the "idea" ("notion", "concept", "abstraction", "intension", "connotation") of a general, universal, object of which objects A and B can be considered particular cases, or "examples". We define O* as the object of the generalizing analogical abstraction.

If, among the innumerable objects that make up our normal observed universe, we recognize some as "similar" since, despite the fact they are composed of different "materials", they have different "colors", different "authors", "titles", "content", and "graphical features, etc., and we describe them as A = book(A), B = book(B), C = book(C), etc., then O* corresponds to "book in general", while A, B and C represent specific books, examples of the idea of book.

Recalling the notion of observative universe in [1], (or of observable universe [2]) we can consider a technical definition [4] or an object of analogical abstraction as an observative universe "field" within which we can observe similar objects.

Formulating *technical definitions* is thus equivalent to "segmenting" the observative universe into "fields", each of which is assigned a specific "O*, object of analogical abstraction", to obtain a "*defined universe*". We assume that the *observable universe*, as defined in [2], includes only 2 dimensions that only admit circumscribed sets of observable values whose means are available to the observer: $UO\,(2) = [D_1, \Delta D_1; D_2, \Delta D_2;\,]$; and also that, considering different pairs of values for the two dimensions, the observer can *describe* different objects – for example, A^1, A^2, A^3, held to be similar and definable by A*, as well as B^1, B^2, B^3, which are similar to each other and definable by B*, etc. – and that in the defined universe the observer can include only 5 *technical definitions* of the abstract objects (ideas): A*, B*, C*, D*, E*. The *defined universe* just described can then be represented as:

$$[\text{def } U^*, 2]=[\text{def } A^*, \text{def } B^*, \text{def } C^*, \text{def } D^*, \text{def } E^*] \quad [5]$$

The model in **Figure 3** makes it easier to understand the preceding ideas. The figures inside UO (2) are technical definitions of the abstract objects A*, B*, etc., and form the defined universe. "X" indicates an "individual" object whose technical *description* is taken as (the first element of) a technical *definition*. The object K is not observable in that universe.

9 – Knowledge and Recognition

Reflecting on our daily cognitive experiences, it is easy to realize that "knowledge" is acquired through the continual action involving the construction of technical definitions, the observation of specific objects, through their technical description, and the "allocation" of the objects based on the most pertinent technical definition. We refer to "knowing" as the operation through with we divide the *observable universe* into *technical definitions*, and "recognition" as the operation through with, after having created the *technical description* of the objects of observation, we identify the appropriate *definition* of them. Knowing leads to the structuring of increasingly larger *defined universes*; with recognition, we go through the defined universe in the search for the most appropriate technical definition. Elementary "knowledge" develops in a continuous cycle of "knowing" and "recognition".

Let us assume we are gazing at the "sky" with a telescope and observing "something new". We use X to indicate this "new object", which must be *recognized*. How does the cognitive process unfold? The first step is to determine the dimensions that normally characterize even well-known celestial bodies. Subsequently, we then search for the existence of a *technical definition* already established previously through which we can recognize the object X as similar to others already observed. If this search is positive, knowledge is acquired and we can conclude: "since object X has these other dimensional states, we can conclude that it is a pulsar".

If the search for the technical definition is not successful, in the sense that X still remains a "mysterious object", then we can create a new technical definition and conclude: "for the first time in the sky a *new* celestial object has been observed whose *technical description* has these other dimensional states; since this description does not match with any of the known technical definitions, the *new* celestial object (and the others that have similar characteristics or dimensional states) are defined and named "X01". The new technical definition has added another element to the defined universe and increased our cognitive and recognitive ability (this element would correspond to object X in **Figure 3**).

Only when the observer can *recognize*, based on a *technical description*, that the *object of observation* corresponds to a given *technical definition* does that object become a "*recognized object*", or simply an "object"; otherwise, to the observer – though probably not for others – it will remain merely a "*thing*". Nevertheless, even "*things*" are objects of observation, but observation in this case cannot, or has not yet, gone beyond the necessary limits to allow the observer to recognize the object under observation. Therefore, for subject S we can narrowly define a *thing* as any observed object for which a single dimension is postulated, "Existence, E", and a single value "existing, e" (for the observer S):

[des *thing*] = [E = e].

Therefore, if, by "bombarding" an atom of a given material, a physicist perceives traces of the *existence* of objects whose technical description does not correspond to any known technical definition in the observed universe of the physicist, then that scientist will be led to conclude "A *new thing* was observed in that experiment". In any event, "knowledge" can never exist in *absolute* terms relative to the *cognitive objectives* of a given subject and the available cognitive *instruments*. This means that, faced with the same object of observation, or the same "portion" of (objective) reality, two subjects can have different motivations for gaining knowledge, and as a result undertake entirely different cognitive activities with respect to different *observative universes*.

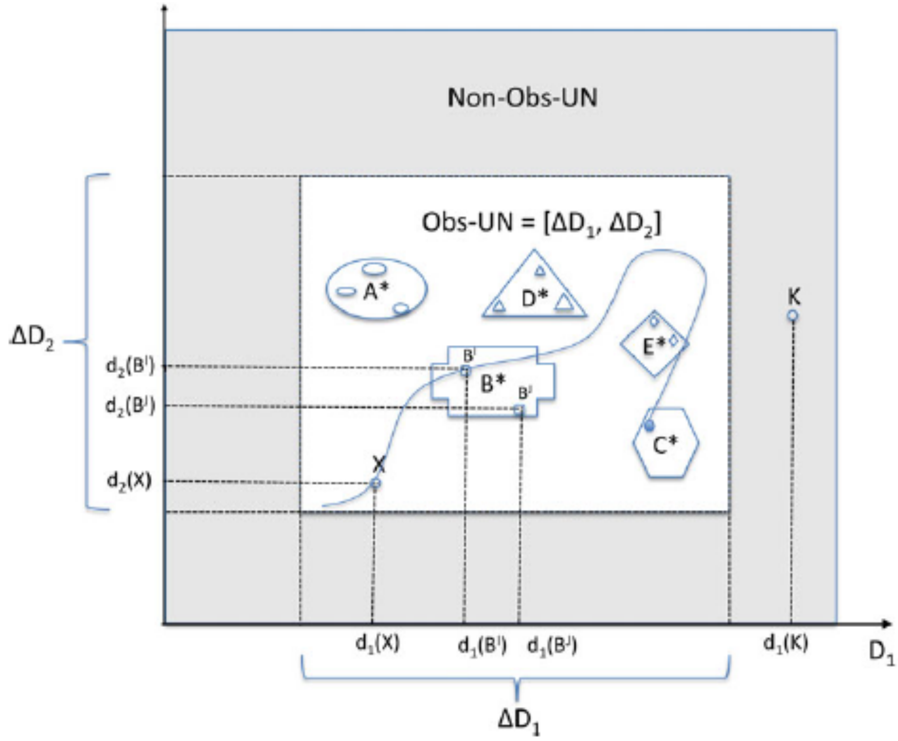

Figure 3 – Observable universe (Obs-UN), descriptions (B^1, B^2) and definitions (A*, B*, etc.) (source: Mella, 2014a, p. 475)

We must also remember that in a given *observable universe* the objects of observation can appear differently based on the "coordinates of observation"; that is, the observers' "points of view". If the differences in the "points of view" cannot be removed, the observation can produce different cognition and recognition for those objects.

For example, when observing a "group" of individuals who cooperate to achieve an objective, the *sociologist* can view it as an "organization" of persons and have as a goal knowing its origins, organic structure and objectives. On the other hand, the *politician* might be interested in analyzing the relations of power, authority, hierarchy and subordination, both formal and informal, among the members. The business economist may want to examine the economic effects of the group's activities and the efficiency and efficacy of those activities in relation to the objectives it has set itself.

Several "points of view" can uniformly modify the values of one or more dimensions in all of the observable objects, thus creating a *distortion* in the observation of the entire "universe". Adopting a highly suggestive terminology, we shall refer to the observative coordinates in this case as "dimensional eyeglasses". The "dimensional eyeglasses" do not characterize the objects or their dimensions but the observers, since they modify their "personal equations".

There are as many "dimensional eyeglasses" as there are dimensions in the observative universe, and the observation will be more or less deformed or distorted based on the "eyeglasses" adopted. For example, the common type with colored lenses distorts the colors in all the observed objects but not their weight, spatial dimensions, and so on. A particular type of "dimensional eyeglasses" is the *observer's value premises*, his religious and political beliefs, his attitude toward life and his "mental models" (Senge, 1990). It is clear that when two observers have different "dimensional eyeglasses", their technical descriptions and definitions may differ regarding the same object.

Therefore, *recognition* can fail when:

1. the observer is not able to (adequately) construct the technical *description* of the object, thus perceiving *things*, not *objects*;

2. the observer cannot identify the technical *definition* of that description;

3. the *objectives* of observation are not specified;

4. the available *instruments* of observation are not adequate or sufficient;

5. the "points of view" of observation are not specified;

6. the "dimensional eyeglasses" chosen by the observer are not known.

10 – Significant Technical Definition

The various mental operations would not be efficient if they did not include *simplifying* activities along with *analogical* ones. The continual search for "simplicity" (even given the subjective connotation of the term) moves us toward *simplification*, without which every generalization would become extremely "burdensome" for efficient observation.
Analogy is possible only following *simplification* since, to detect analogy, even given the specific differences observable in objects (particular dimensional states), the observer must neglect what appears as "superfluous" in order to "retain in perception" only those dimensions (and their states) it is deemed can be usefully matched. For this reason, concrete observations limit the extension of the observative universe, including in it only those dimensions useful for the aims of the investigation and neglecting those held to be irrelevant.

When we search for the *technical definition* of an *object of analogical abstraction*, many of the dimensions of the observative universe can be neglected since their inclusion would make the *technical definition* so complex and redundant that it would not be efficient. Therefore, the observer tries to minimize the number of dimensions he considers in the defining activity to produce minimal technical definitions, or *significant technical definitions*, which mentally correspond to the "understanding" of object O* of the analogical observation. These definitions can be expressed in the following way:

$$[\text{def min } O^*] = [(D^*_1, \Delta d^*_1), \ldots, (D^*_{N\,min}, \Delta d^*_{N\,min})] \qquad [6]$$

Recalling [5], to significantly define "the" square it is enough to consider the following dimensions and ranges of variation:

[def min "the square") = ["observation space: two-dimensional plane"; "number of sides: four"; "length of sides": equal"; "width of angles: equal"]

Every other dimension such as the effective length of the sides, the name assigned to the angles, the orientation of the plane, the color of the area, and so on, is irrelevant for a significant definition, though essential in the technical descriptions of actual squares.

Though it should be clear by now, it is worth noting again that both the *technical definition* in general and the *minimal definition* in particular can be formed differently depending on the observer who is producing them; his "personal equation" can affect both the number and type of dimensions considered as well as the extent of the admissible ranges of variation. Many significant definitions include even only a single dimension held to be particularly representative. We shall call such definitions *elementary*.

Among the many types of *elementary significant definitions* are the following:

a. *ostensive* definition: this allows the observer to form the analogy by simply indicating several examples of the object of analogical abstraction ("what is a book?"; "any similar object to those you see in my bookcase");

b. *extensive* definition: this lists "all" the objects (extension) that must be included in the definition ("stakeholders are the group that supplies controlling capital, the suppliers of controlled capital, the workers as a group, the relevant clients, etc.");

c. *genetic* definition: this highlights the origin of the objects to be included in the definition ("the financial report is any document that represents the output of financial accounting");

d. *structural* definition: this highlights the structure of the defined objects ("the cost of production of a quantity Q is the sum of the costs of the factors consumed in a given period to obtain Q");

e. *modal* definition: this indicates the composition of the objects included in the definition ("the statement of assets and liabilities is the document that indicates the assets, liabilities and net capital at the end of the administrative period");

f. *functional* definition: this highlights the function of the objects in the definition ("the organization is a group of subjects who operate in a restricted, structured, coordinated, cooperative, and continuous way to achieve a general objective");

g. *instrumental* definition: indicates the possible uses of the defined objects ("a machine is any apparatus that transforms material and components into products by following operational programs");

h. *teleological* definition: this considers the objectives of the objects of observation ("the firm is the organization that sets the profit objectives");

i. *operational* definition: this specifies the operations needed to identify or recognize the objects of observation that enter into the definition ("income is the difference between the value of production sold through an exchange and the value of the factors productively employed to obtain this based on the matching principle and a system of accepted accounting principles"). The operational definitions are particularly effective in defining abstract or composite objects.

11 – Models

"Reality", or more specifically the *observed universes*, precisely because they are composed of a plurality of objects, are always multi-dimensional and closely interrelated. "Reality" is almost always too complex to observe, either scientifically or operationally, thus making it necessary to simplify by constructing *models of reality*.

A model can be considered the instrument through which we can *approximately* represent the results of the observational activity. The model can be a simple one (graphic model of a single object of observation) or a complex one (in the forms that will be presented in the following sections).

However composed, and for whatever purpose, models have a common feature: they are *approximate representations* of reality. *Approximation* is a necessary feature for any model, as otherwise we would be constructing a duplicate of the original, not its model. Though necessary, *approximation* must nevertheless not go beyond the limits that would turn the model into too vague a representation, and thus useless. The *approximation* must be convenient. It may even be necessary operationally, since it may be the sole means for observing too complex a reality, or a unique one than cannot be tampered with.

The construction of models creates a correspondence between the chosen dimensions of the *reality* being investigated and the universes of observation, on the one hand, and the dimensions of the model on the other, based on the logic presented in **Figure 4**.

Since models are *formal* depictions of the results of observative activities, it is useful to deal with them only after an analysis of "languages", through which communication and formalizations are carried out. However, some preliminary remarks on this topic are helpful here.

Among the many possible classifications of models, a particularly relevant one is that which distinguishes between:

a. descriptive models,

b. operational and simulation models.

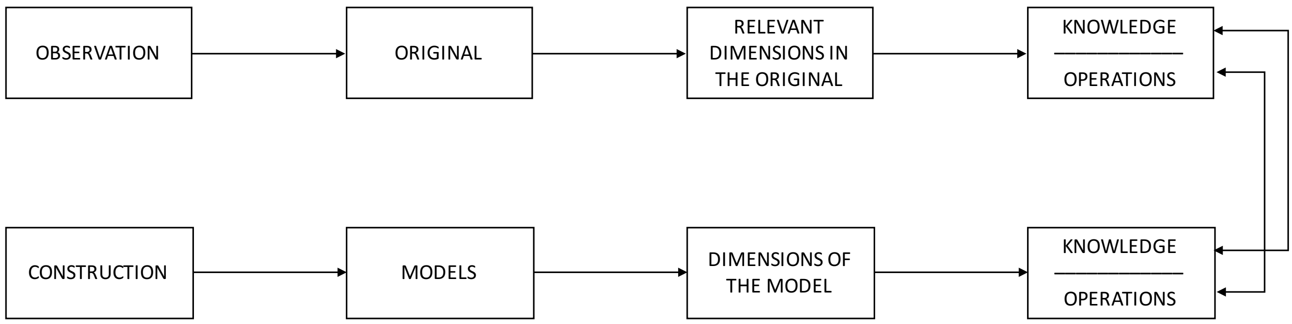

Figure 4 – The logic of model construction

The first type depict a given *object of observation* by means of a technical *description* of an approximate technical *definition*. Operational models, on the other hand, are structured to allow for the *simulation* of the *behavioral data* of reality and of the dynamic objects of observation. A painting can be an acceptable descriptive model of a ship, but to simulate the resistance of a real ship to wave movement, a scaled operational model is necessary. A formal model that expresses the principal and interest (M) after N years as the sum of the capital (C) and interest (I) for each of the N years is a *descriptive* model. An *operational* model is instead one that allows us to calculate the actual principal and interest as compound capitalization, given the years N and interest rate "i": $M(C, N, i) = C(1+i)^N$.

All *simulation models* constructed to simulate the behavior of the objects of observation are *operational* models; for example, apparatuses to simulate earthquakes and the resulting structural damage and the system of differential equations to simulate growth in an economic system.

Another important distinction is that between:

a. literary models, which are constructed through a literary language;

b. symbolic models, formed through conventional signs of a symbolic language; mathematical and logical models belong to this category;

c. schematic models, which rely on graphical signs which are not immediately linguistic;

d. iconic models, which rely on representations that "resemble" the original regarding a number of dimensions.

Linguistic models, both literary and logical-mathematical, permit a nearly unlimited representation of the dimensions of the depicted objects. On the other hand, schematic ones, even though they imply a more limited range of representational possibilities, offer the advantage of immediacy and the possibility of highlighting relations in *structural* terms. In fact, while languages provide a *sequential*, or linear representation of the dimensions of objects, the use of diagrams allows us to overcome this limitation (for a more detailed classification of models, see Mella, 1982, p. 121).

12 – Models Are the Source of Knowledge

Models are the basic instruments of our intelligence since it is possible to hypothesize that (our) thought process constructs "mental models" of the world assumed to be formed in the mental sphere of individuals and which, though approximate, are indispensable for intelligent thought, being the basis for an understanding of reality and for interacting with other individuals. The psychologist Philip Johnson-Laird analyzed the cognitive function of mental models in his book Mental Models: Towards a Cognitive Science of Language, Inference and Consciousness (1983), an analysis that was taken up again in many of his subsequent works.

The psychological core of understanding, I shall assume, consists of having a "working model" of the phenomenon in your mind. If you understand inflation, a mathematical proof, the way a computer works, DNA, divorce, then you have a mental representation that serves as a model of an entity in much the same way as, say, a clock functions as a model of the earth's rotation . . . Many of the models in people's minds are little more than high-grade simulations, but they are none the less useful provided that the picture is accurate (Johnson-Laird, 1983, pp. 2-4).

Jay Forrester (1961) and Peter Senge expressed a similar idea.

The mental image of the world around us that we carry in our heads is a model. One does not have a city or a government, or a country in his head. He has only selected concepts and relationships, which he uses to represent the real system (Forrester, 1971, p. 213).

"Mental models" are deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action. Very often, we are not consciously aware of our mental models or the effects they have on our behavior. For example, we may notice that a co-worker dresses elegantly, and say to ourselves, "She's a country club person." About someone who dresses shabbily, we may feel, "He doesn't care about what others think" (Senge, 1990, p. 8).

Our 'mental models' determine not only how we make sense of the world, but how we take action (Senge, 1990, p. 160).

Obviously, as they are produced "in the private sphere", mental models are not sufficient for effective thinking, revealing a clear limit: not only can they be imprecise and vague but they are also often erroneous and can be strongly influenced both by the opinions and beliefs about the world expressed by the thinking subject (Lippmann, 1922), which often do not even correspond to an observable world (for example, Dante's "afterlife" model of Hell, Purgatory and Paradise), and by personal judgments, which are often misleading (Senge, 1990).

Therefore, to make thinking more precise and suitable for action, man, from the time he became "sapiens", produced lexical and symbolic language to construct and communicate in a precise manner and to produce effective actions.

The only feeling that anyone can have about an event he does not experience is the feeling aroused by his mental image of that event. That is why until we know what others think they know, we cannot truly understand their acts (Lippmann, 1922, p. 13) .

One thing is certain: understanding, explaining, communicating and acting are not possible without the use of models (Mella, 2014b). Models are the tools of our intelligence, and I am convinced that intelligence can be thoroughly and operationally defined not as a simple cognitive process characterizing thought but as an aptitude, an "ability" to construct coherent and sensible models (Mella, 2012) to acknowledge, understand and communicate the world (and thus to pass the Turing Test; Turing, 1950); in particular, I believe that intelligence is the ability to develop a system of coherent and meaningful models that allow us not only to survive in a world that is continually evolving but also to improve ourselves and make progress:

Intelligence may be conceived of as the ability to rapidly and efficiently construct or update the models of knowledge and arrange them into coherent "bodies of knowledge"; and to quickly learn to use them to survive in a changing world. Intelligent persons understand (and comprehend) quickly and effectively. … Intelligent persons are those … who are not content to "look at the world with their eyes" (objects, facts, phenomena and processes) but who are able "to see the world with their minds" by constructing models to "understand" how the world is (description), how it functions (simulation), and how we can act as part of it (decision and planning), even without having the need, or possibility, of "looking at everything" (Mella 2012, p. 3).

This capacity "to see" and not simply "look at" depends on the "ability" to construct models to understand, explain and simulate the world. Intelligent people quickly modify their models after having observed the consequences of their actions in the world (Argyris, 1993; Argyris and Schön 1978, 1996; Sterman, 2000).

Furthermore, intelligence itself does not consist of an isolated and sharply differentiated class of cognitive processes. It is not, properly speaking, one form of structuring among others; it is the form of equilibrium towards which all the structures arising out of perception, habit and elementary sensory-motor mechanisms tend. It must be understood that if intelligence is not a faculty, then this denial involves a radical functional continuity between the higher forms of thought and the whole mass of lower types of cognitive and motor adaptation; so intelligence can only be the form of equilibrium towards which these tend (Piaget, 2003, p. 7).

There are several important types of models, of which the following are particularly useful:

a. Descriptive and operational models.. Descriptive models serve to describe or explain the object they represent by presenting the relevant dimensions through some language or schema, determined by the operational objectives the subject wishes to achieve through the model.

b. Scale and analogic models. These classifications are based on the type of approximation the model introduces in the represented phenomena. Scale models maintain the initial quantitative dimensions and the ratios between them (changing only the distance); analogic ones depict the original dimensions through different dimensions while respecting the ratios (and/or relations and/or distances) already observed in the represented object.

c. Static and dynamic models. The former depict structural relations among the components of a system that do not evolve over time (a company's balance sheet is a typical static model of values; a constellation and a city map are descriptive static models). Dynamic models, on the other hand, consider time (or space) as a fundamental variable; every dynamic dimension of the original must be appropriately depicted in the model (for example, models that represent self-controlled systems are dynamic).

d. Qualitative and quantitative models. The distinction here refers to the type of dimensions held to be fundamental more so than to the results achieved. Models that, irrespective of their conformation, represent quantitative dimensions from the original are *quantitative*. Qualitative models instead highlight the qualitative dimensions.

e. Deterministic and stochastic models. In this case the distinction regards the way the relations represented in the model are determined, typically when the model concerns dynamic systems. Probabilistic models hypothesize that the inputs and/or outputs are random variables whose probability distribution is assumed to be known.

13 – Advanced Observative Activities

Observative activity is not limited to identifying objects, describing them and articulating technical definitions. On the contrary, such operations are the premise for more "advanced" observative activities through which man can provide *explanations* to understand and *predict* certain phenomena in the real world in order to control events, where possible. All "advanced" observative activities have one thing in common: they give a specific order to the objects of observation. There are different *degrees of order*, to each of which there is connected to an increasingly complex observative activity, which we can divide into the following types:

a) *grouping,* that is, the activity aimed at identifying *sets*; this involves the activity of *classification*;

b) *systematization,* the activity that creates *systems*;

c) *formulating laws*, the search for uniformity, or *laws*;

d) *theorizing*, the activity of *interpreting* and *explaining* the entire observative universe or ample portions of it through the ideation of scientific *theories.*

Each of these observative activities requires broad treatment; however, in the present theoretical context, only several basic considerations will be presented.

14 – Sets and Classifications

After the technical *description* of the objects, one of the most frequent observative operations is the formation of "sets" – which I will call grouping – which consists in "bringing together" in the observational activity several objects that are distinct but characterized by a common *dimension* (all colored objects), a common *dimensional state* (all red objects), or a common *range of variation* (all objects weighing 10 to 13 kg). A "set" is formed when a plurality of distinct objects, characterized by a common attribute, are viewed by an observer as a single object, a "set". Like the observative activity of *objects* analyzed in section 2, the formation of sets, or *grouping*, is also a "constitutive" operation since it does not describe the object "set" (group) but "constitutes" it as an independent object of observation; in fact, in the logic and algebra of sets, these are normally defined as primitive "entities", which can only be expressed by using synonyms.

In any event, it is important to observe that groups are normally formed by a multitude of non-ordered objects; more precisely, by objects whose only ordering criteria is the possession of the characteristic common to all of them. This fact does not change by "moving" an element of the set inside the set itself. The objects in the set have no other ordering criteria than that of being a "set".

Grouping immediately leads to *classification*, which seeks to form sub-groups, or *classes*, of objects of observation forming a given *universe of classification*. Each class is characterized by one or more *dimensions* and/or states and/or one or more ranges of admissible variation. More precisely, each class is characterized by a specific *technical class definition* that identifies and delimits the *class intervals*. The classification is essentially carried out through *identification*, which describes the objects to classify and assigns them to the class whose technical definition encompasses the technical description of the objects to be classified.

Classification assumes a universe to classify composed of M>1 pluridimensional objects, which are indicated by the following notation:

$$CLU = [O^1, ..., O^m, ..., O^M], M>1 \qquad [7]$$

where: $des[O^m]$, $1 \le m \le M$, are the technical descriptions of the M objects.

To carry out a *one-dimensional*, or *simple* classification, we identify one of the dimensions common to all the objects, for example, D_n, and specify in it K *determinations*, or, more generally, $K \ge 2$ *ranges of state* (quality or quantity) that represent *significant class ranges*:

$$\Delta_1 d_n, ..., \Delta_k d_n, ..., \Delta_K d_n$$

We then *identify* the O^m by observing the $desO^m$ of each object in [6] to form the K distinct classes. The object O^m is assigned to the kth class if:

$$[d_n \in des\, O^m] \subset \Delta_k d_n \ .$$

The classification is *multiple*, or *multi-dimensional*, if it is formed by jointly considering several dimensions. This allows us to form classes whose *class intervals* derive from a variety of ranges of "determination" considered contemporaneously. The multiple classification involves "several stages" if, when considering the dimensions D_1 and D_2, we first *identify* the objects into classes based on D_1; each of these classes, considered as an autonomous universe of classification, is divided during a second phase into subclasses based on D_2. With regard to multiple classifications produced over several stages, it is useful to keep in mind that:

1. it is fundamental to define the class intervals appropriately and to avoid "losing" objects that do not enter into any of the defined classes;
2. if possible, the formation of empty classes must be avoided;
3. during the initial stages, it is thus necessary to choose the dimensions and dimensional ranges so as to allow for the formation of classes with a "number or elements" that is not too dissimilar;

4) choosing incompatible dimensions must be avoided;

5) it is useful to maintain symmetry in the classification.

15 – Systems and Structures

Systematization is the second of the *advanced* observative activities, and certainly one of the most important for scientific knowledge. *Systematization* occurs when we "arrange" or "identify" an "order" of some kind for several objects of observation (or "entities"), with the result that these objects are interrelated and lose their observative individuality to become elements in a new entity: the "*system*". Just as the pastor in Asia, when observing a starry sky, arranges the stars to form the imaginary constellations, so the biologist, by ordering the living species, forms "natural systems". And just as Eiffel, in planning the shape, position and links among thousands of iron beams, created the famous tower, so the anatomist identifies the relations among the elements in the human body to form the skeletal system, the muscular system, the nervous system, the circulatory system, and so on.

Similar to *grouping*, *systematization* is also "constitutive" in that the *system* represents an object of composite observation resulting from the determination of an order among elementary objects that lose their "singularity". Therefore, what results from observation is a unity (constellation, natural system, skeletal system, etc.), even though the constituent elements (stars, living beings, bones, etc.) are singular and varied. The elements of the system become *unified objects* (Klir, 1991) even if they are also *composite* (Section 7). Ludwig von Bertalanffy provided the following general definition of system:

A system can be defined as a complex of interacting elements. Interaction means that the elements, p, stand in relations, R, so that the behavior of an element p in R is different from its behavior in another relation R'. If the behaviors of R and R' are not different, there is no interaction and the elements behave independently with respect to the relations R and R' (von Bertalanffy 1968, p. 55).

This definition highlights that each system has its own emergent characteristics compared to those of its constituent parts (. Thus the definition of dynamic system as a dynamic unity composed of interconnecting and interacting variables is justified (La´szlo´, 1983). Naturally, a dynamic system derives from a system of processors that produce the dynamics in the input (causes) and output (effects) variables.

The objects and the relations that link them into a system can be of various kinds; what is important is that the objects have a given order in the system, specified by the relations, so that "by modifying the placement" of one of the objects in the system, or "changing" one of the relations that link them, the "system" is also modified. Following von Bertalanffy, systems can be *real* or *conceptual*

What is to be defined as a system and which things are describable as such are certainly not questions to which we can give an obvious or simple response. It is easy to agree on the fact that a galaxy, a dog, a cell and an atom are real systems -- that is, entities that are perceived by observation or inferred from this, and which exist independently of the observer. On the other hand, there are conceptual systems, such as logic and mathematics (including, for example, even music), which are essentially symbolic constructs; that is to say, conceptual systems corresponding to reality (von Bertalanffy 1968, p. 16).

A clear definition and external description is given by Gary Sandquist (**Figure 5**), who considers the *cause-effect system* and proposes the following definition:

[A system is:] Any collection, grouping, arrangement or set of elements, objects or entities that may be material or immaterial, tangible or intangible, real or abstract to which a measurable relationship of cause and effect exists or can be rationally assigned (Sandquist, 1985, p. 22).

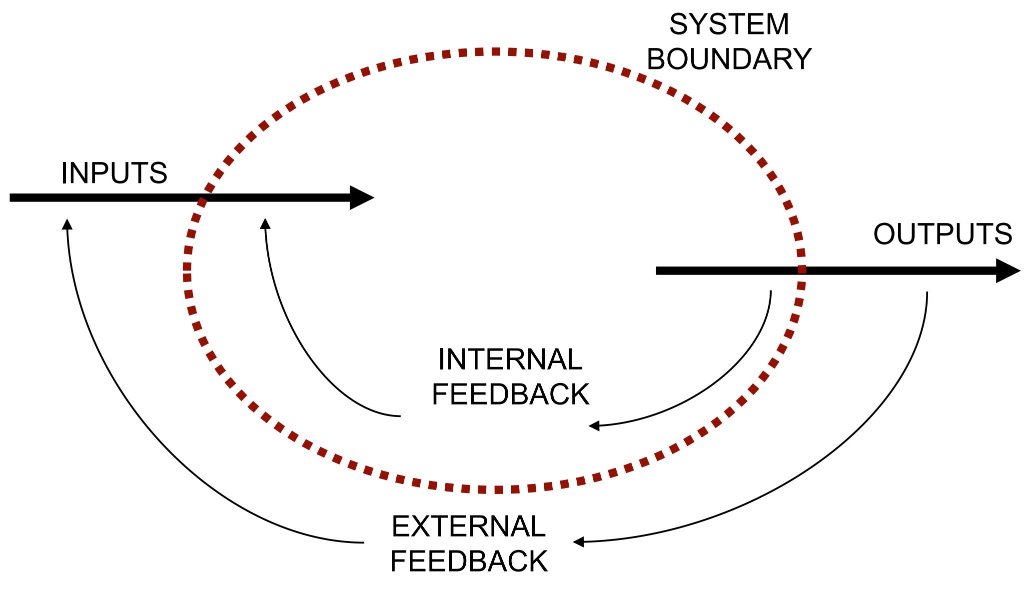

Figure 5 – Model of a cause-effect system (source: Sandquist 1985, p. 22).

Many systems can be viewed either as composed of subsystems or as part of a macro system. Like the distinction between simple and composed objects, that between systems and subsystems is not absolute but depends on the objects of the scientific and operational observation. In reality, or in certain observed universes, we frequently find composite objects formed of elements linked through others that connect them, or various groups of objects *actually* linked or interrelated by means of others that serve as relations of connection. For example, consider a human organism in which the bones are *actually* connected by tendons and muscles to form the autonomous skeletal structure, a lighting system where the light bulbs, light switches and outlets are *actually* interconnected by means of electrical cables, or the Eiffel Tower where the iron beams are *actually* connected by bolts.

To distinguish physical systems from those resulting from constitutive observational operations, we shall refer to the former as *structures* and use the term *system* for every other object, not necessarily physical, for which we can identify elements and relations.

A *structure* is a unitary composite composed of a plurality of correlated and/or interrelated elements such that:

1. it has its own characteristics, its own states, which derive from the characteristics and states of its elements, even though it does not identify itself with any of these;

2. the state of each element depends on the state of at least one other element and is thus conditioned by the state of the entire structure;

3. if the structure must assume or modify its own state, some elements must assume a given state or undergo a modification of state;

4. all the elements are necessary to form "that" structure.

The structure is at the same time structured (its state derives from that of its elements) and structuring (its state conditions that of the elements).

A chair, a clock, a bridge, a team of horses pulling a cart, a soccer team: these are all structures. It is easy to recognize the component elements and equally easy to understand that the structures are different from these elements.

The distinction between system and structure is important since, while the structure is an object of composite observation, the system is the result of an observational activity. A necessary and sufficient condition for a composite "object" to be defined as a "system" is that the observer can note three constituent characteristics (Wasson, 2006):

a. the system must be observable as a lasting unit (synthetic vision) with its own significance (macro) which, though deriving from that of its elements, appears new and emerging;

b. the elements of the system (micro) contribute to the existence of the system as a whole but subordinate their own states to the existence of the system (analytic vision);

there is thus a permanent correlation (micro-macro feedback) between unit and elements: on the one hand, the system becomes a unit even in the multiplicity of its constituent parts; on the other, the parts lose their individuality in the system, becoming equally essential to the formation of the unit (**Figure 6**).

These three constituent characteristics point out (define) the so-called synergetic effect (Haken, 1977a, 1982; Gilbert, 1999)), that is, the phenomenon by which the system's elements, inserted in the structure, produce a global effect (usually considered to be "greater" and, in any case, emerging) that is different from that which would have been produced by those same elements considered on their own.

It appears to leave human organizations and institutions little different in principle from wasp's nests or even piles of sand. They can all be said to emerge from the actions of the individuals. The difference is that while we assume that, for instance, wasps have no ability to reason – they just go about their business and in doing so construct a nest –people do have the ability to recognize, reason about and react to human institutions, that is, to emergent features. Behaviour which takes into account such emergent features might be called second order emergence (Gilbert 1995, online).

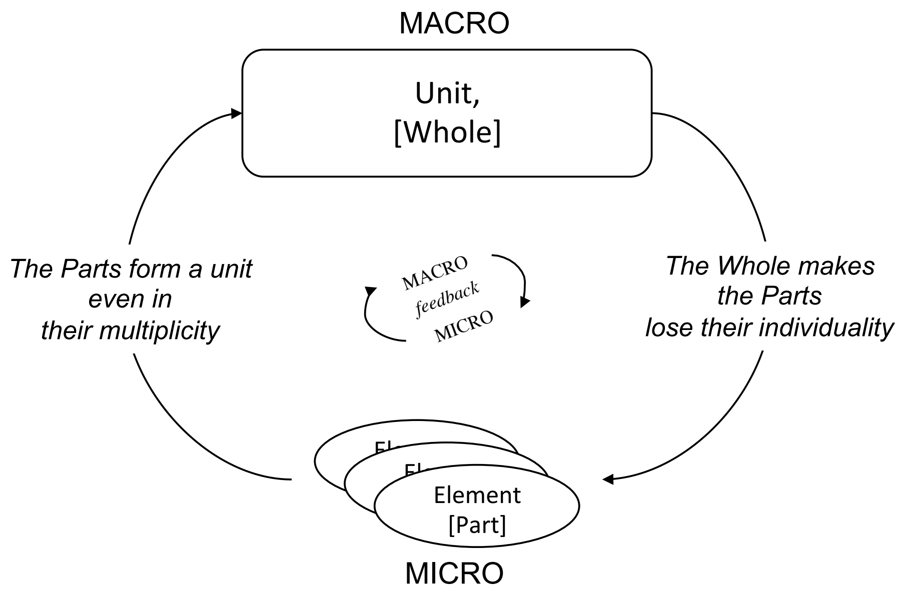

Figure 6 – The three characteristics constituting a system

Just as, on the one hand, the same structure can be observed in different systemic terms by different observers, based on the objectives of observation of the latter, on the other hand, non-structured objects can be observed in systematic terms if it is possible to determine relations that join them together in a system. For example, a motor is a structure, but the pieces it is composed of can, when disassembled, equally be observed as a "system of motor components" by a mechanic who must reassemble them. Moreover, those same components, even before they are actually produced in physical terms, represented the "system of the structure of the motor" in the mind of the planning engineer. Conversely, there is no structure that corresponds to the information system. On the other hand, a structure normally underlies the information technology system. What are the relations that bind together the stars of the Great Bear constellation, the books in a library, or the atomic elements in Mendeleev's table into a system?

According to the above definitions, all the machines built by man, all the biological organisms, all organizations and firms are systems (Beer, 1979, 1981). Mathematical "systems", number vectors and matrices are systems; as are the streets in a neighborhood, the highways, or a region's electric lines. Even libraries arranged with books or a group of insects or individuals who coordinate activity among themselves are systems as well. The same is true for the multiplication table, Mendeleev's periodic table of elements or a constellation. A group of planets that orbit around a sun is a system just as is group of particles that orbit around a nucleus; and so on. If an "object" cannot be broken down further it is not a system; at most, it is an element of a larger system. The dismembered parts of an organism or the disassembled elements of a watch are not systems. A pile of rocks that the waves arrange on the beach according to size, or a herd of elephants grazing lazily on the savanna are not systems. All the elements that form unorganized groups are not systems.

16 – Systems: a Basic Typology

Systems can be observed and classified according to a variety of observative dimensions (Boulding, 1956; Skyttner, 2005). Since a system "is" not a structure but "has" a structure, if we consider the nature and significance of the elements that form the structure, we can distinguish two large classes of systems:

1. *organized*, *structural* or *operative* systems: the structure of these is composed of elements which differ from each other; these elements are defined as *organs* of the system, since they have a precise spatial and temporal placement, carry out a specialized function in relation to the entire structure, and have a specific functionality that delimits the admissible interactions with the other elements. Since the organs undertake operations, such systems are also called operative; the component elements (usually processors) are connected by a map of defined and stable relations forming the invariant organization of the system, according to Maturana and Varela's interpretation (1980) so clearly described by Stafford Beer in the Preface to their work.

The relations between components that define a composite unity (system) as a composite unity of a particular kind, constitute its organization. In this definition of organization the components are viewed only in relation to their participation in the constitution of the unity (whole) that they integrate. This is why nothing is said in it about the properties that the components of a particular unity may have other than those required by the realization of the organization of the unity (Beer 1992, p. XIX).

A unit realized through a closed organization of production processes such that (a) the same organization of processes is generated through the interaction of their own products (components), and (b) a topological boundary emerges as a result of the same constitutive processes (Zeleny 1981, p. 6).

2. *unorganized* or combinatory systems; these are made up of elements of a similar nature, or similar significance, that develop similar interactions (behavior, processes) which, combining together, produce emerging effects with reference to the unit. Since the elements are similar they do not constitute organs, and thus such systems are unorganized. They are called "combinatory" precisely because what we observe at the macro level derives from the combination of what is produced at the micro level.

A "combinatory system" is defined as any collectivity (see Def. 1) made up of a plurality of unorganized similar agents (or elements) producing analogous micro behaviors and showing, as a whole, a macro behavior and/or a macro effect, whose dynamics are created by a micro-macro feedback action. If, on the one hand, the macro behavior of the system, as a whole, derives from the combination, appropriately specified, of the analogous behavior (or effects) of its similar agents (hence the name combinatory system), on the other hand the macro behavior (or the macro effect) determines, conditions or directs the subsequent micro behavior, according to a feedback relation between the micro and macro behavior or effects (Mella, 2017, p. 8)

3. *complex* systems, if the elements of a combinatory systems are different in nature and develop different interactions. By definition, a complex system is composed of a large number of interacting elements, often not individually observable, whose dynamics, starting from a present state, are non-linear and intrinsically uncontrollable (Casti, 1985; Wolfram, 1984) and may lead to unpredictable emerging states (Prigogine and Nicolis, 1989; Coveney and Highfield, 1995; Gleick, 1987; Kellert, 1993; Waldrop, 1993). A complex system is literally one in which there are multiple interactions between many different components (Rind, 1999, p. 105).

Many natural systems (e.g., brains, immune systems, ecologies, societies) and increasingly, many artificial systems (parallel and distributed computing systems, artificial intelligence systems, artificial neural networks, evolutionary programs) are characterized by apparently complex behaviours that emerge as a result of often nonlinear spatio-temporal interactions among a large number of component systems at different levels of organization (Honavar, 2006, online).

Included among the complex systems is the specific class of Complex Adaptive Systems (CAS) (Holland, 1992, 1995; Kauffman, 1993, 1996; Heylighen, 1989; Khalil and Boulding, 1996); that is, systems with the capacity for structural adaptation and organizational evolution, as shown in this concise definition:

Definition (1): A CAS consists of inhomogeneous, interacting adaptive agents. Adakenptive means capable of learning. Definition (2): An emergent property of a CAS is a property of the system as a whole that does not exist at the individual elements (agents) level. Typical examples are the brain, the immune system, the economy, social systems, ecology, insects swarm, etc. (Ahmed et al. 2005, pp. 1–2)

According to Murray Gell-Mann (1992, 1994, 1995), the category of CAS should also include all the basic components of this system as well as individuals who can survive by adapting their behavior and producing new schema of interaction and coexistence that allow this behavior to be predicted and adapted to.

Now how does a complex adaptive system operate? How does it engage in passive learning about its environment, in prediction of the future impacts of the environment, and in prediction of how the environment will react to its behavior? [. . .] The answer lies in the way the information about the environment is recorded. In complex adaptive systems, it is not merely listed in what computer scientists would call a look-up table. Instead, the regularities of the experience are encapsulated in highly compressed form as a model or theory or schema. Such a schema is usually approximate, sometimes wrong, but it may be adaptive if it can make useful predictions including interpolation and extrapolation and sometimes generalization to situations very different from those previously encountered. In the presence of new information from the environment, the compressed schema unfolds to give prediction or behavior or both. (Gell-Mann, 1992, p. 10)

Using a simple symbology, an organized system S, defined in a specific environment [A], can be represented as the result of the *application* (existence, action, influence, etc.) ("⊗") of a set of stable *relations*, [R], to a set of elements, [E], such that the observation can be directed toward:

$$[\text{Obs}] \Rightarrow \{ [A] \leftrightarrow S \leftrightarrow \{[R] \otimes [E]\} \} \qquad [8]$$

where the term S indicates the *unit of synthesis* – the "object" concerning which the *observer*, [Obs], *notices*, "⇒", the emerging unitary characteristics. The unit S is composed of the *plurality* of the elements of the set [E] – each having its own *analytic characteristics* – by means of the set of relations [R]. The relations that are stable over time form the organization of the system. The term {[R] ⊗ [E]} indicates the *formation of the structure* of the system, the term [A] all that which is not system; that is to say, the environment with which S interacts. A system is defined as *interactive* if its structure, through some of its elements, can receive *stimuli* (perturbations, actions, etc.) and, without coming undone (that is, conserving its structural ties), can emit through other elements new stimuli we can consider to be an *answer.* In other words, a system is structurally linked to the environment if there are *receptors* and *effectors* in its structure through which the system interacts with the macro system. A pair of received and emitted stimuli represent an environmental *interaction.* In order for an interaction to occur, some elements of the structure must alter their *state*; each element that can change its own state to receive and emit stimuli is defined as a *processor.*

The modification (Δ) of the state of a processor is defined as an *elementary process* – or *operation*. The *stimulus received* is called an *input* for (of) the process; the *stimulus emitted* is called an *output* (if the processor does not emit stimuli we can take the new state as the output). A processor (or group of processors) specialized to receive environmental inputs of a given type and transmit them to other processors "down the line" is defined as a *receptor organ* or *input receptor*. A processor specialized to emit environmental outputs that follow from stimuli received from other processors "up the line" is defined as an *effector organ*.

The system, as a unit, must interact with the environment in a continuous way. The behaviour of the system (environmental dynamics) cannot consist only of a single process of environmental interaction but must correspond to a repetition (flow) of processes. This brings out three fundamental aspects of the dynamics of a system (**Figure 7**):

1) the *dynamics* of each system depends on its *structure*;
2) a system can exist only if the *structure* is *appropriate* for the processes to be undertaken;
3) as a result, the *processes* must be *coherent* with the *maintenance of the structure*.

An *element of the structure is appropriate* if, with respect to the *organization*, it possess the specificity necessary for carrying out the processes according to stimuli that come from processes "up the line" and according to stimuli aimed at processes "down the line". Two *processes* are *coherent* with each other if they give rise to variations in the state of the structure which are compatible with the whole of the admissible variations in the state of the elements that compose the structure.

We can define the set of dynamics (macro-processes) produced by the system before the structure disintegrates as the *existence* of a dynamic system. A system with an inappropriate structure with respect to the environmental stimuli cannot carry out coherent reactive processes, and will thus be destined for destruction.

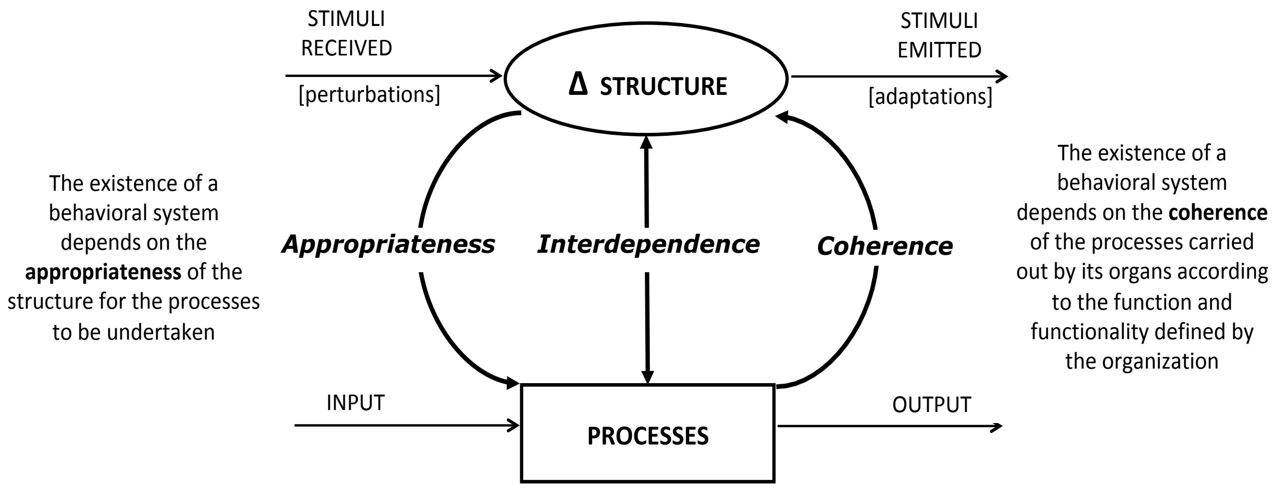

Figure 7 – Appropriateness and coherence of structures and processes

A system that cannot interact (or for which observing interactions makes no sense) and whose structural elements do not change their state is defined as *purely ordinal* or *static*. In this sense a matrix, a collection of stamps, Mendeleev's periodic table of elements, a library are ordinal systems; a bridge, a skyscraper, even the Eiffel Tower, are static systems, even if some form of interaction is always possible in theory for some observers. **Figure 8** indicates how we can define the systems that have no structure or that do not produce processes.

A dynamic system thus appears as an organized structure of appropriate processors which produce a network of coherent processes that give rise to an emerging behavior (Mella, 1997).

		THE SYSTEM HAS A **STRUCTURE**?	
		YES	NO
THE SYSTEM CARRIES OUT **PROCESSES**?	YES	The system is CONCRETE Ex.: living beings machines ES	The system is ABSTRACT Ex.: ocean tides, weather system
	NO	The system is ORDERED Ex.: Eiffel Tower, matrix, puzzle	There is no system but only an ELEMENT OF A SYSTEM

Figure 8 – System structure and processes

A system is defined as *open* if it produces (or if we can observe in it) processes that involve inputs and/or outputs with the environment; the network of processes is activated by inputs and can emit outputs. The *dynamics* that define the behavior of an open system can be represented as the sequence of inputs, outputs and processes that develop over a period T. If the structure is known, so that we know the operations that make up the process, then the system is a *white box*; otherwise, the structure is a *black box*; and we can write:

$$\textit{dynamics of an open system} = [t, I(t), P(t, t'), O(t')] \quad [9]$$

where

- I(t) and O(t′) are correlated inputs and outputs

- P(t, t′) = process that correlates them = ΔS(t) = [S(t), S(t′)], the dynamics of the states of the structure from t to t′.

A system is defined as *closed* if, even though its structure has a dynamic state, it does not permit interactions (or if the observer does not think it necessary to note these). The dynamics are defined simply as structural dynamics:

$$\textit{dynamics of a closed system} = [t, \Delta S(t)]$$

An *important consideration* arises: the distinction between open and closed systems assumes that the observer is in the external environment of the system, so that he can describe inputs and outputs between the environment and the system. This distinction is valid for the external descriptions.

A *dynamic system* observed over a period T is defined as *without memory* if:

i. the dynamics depend on the states of the structure but *not directly on time* (time is not an explicit variable that conditions the processes);

ii. at the end of the process the structure always returns to the same state, so that the next process can repeat itself from the same initial state; or the inputs determine the internal state from which the process begins;

iii. every I(t) thus produces an O(t′), independently of the instant t at which I(t) occurs;

iv. each flow of I(t) always produces the same flow of O(t′) in T.

A system instead "has" memory if:

i. the input I(t) finds the structure to be in state S(t) and causes the structure to modify its internal state from S(t) to S(t′), producing the output O(t′); nevertheless, the system does not return to its original state but remains in S(t′). By repeating the cycle, an input I(t′) = I(t) brings the system from S(t′) to S(t′′), producing the output O(t′′), which is not necessarily equal to O(t′);

ii. each I(t) thus produces an O(t′) that depends on the instant t at which I(t) is revealed;

iii. each flow of I(t) does not necessarily produce the same flow of O(t′) in T;

iv. the dynamics depend on on the moment in which the system begins its evolution.

The inputs and outputs of an *open system* are always forms of energy that allow the system to carry out its processes; nevertheless, we can divide these into three main classes:

a. *instructive* inputs/outputs: instructive inputs (or information, commands, rules) are perturbations of receptor organs (forms of energy inputs) that indicate the state these must assume; all the other processes of the network originate from this initial state. The instructive outputs are represented by the state of the effector organs produced at the end of the internal processes, which produce some effects (energy output) on the environment;

b. *energy* inputs/outputs; inputs are represented by energy flows (of whatever kind) that allow the structure to carry out the modifications in state; the outputs are energy flows that the structure yields to the environment;

c. *instrumental* inputs/outputs; these are flows of elements, material or of a different kind, that undergo some form of transformation in processor systems.

A succession of *instructive* inputs that produces specific conformations in the state of the system's internal organs in such a way that these can then produce specific processes when other inputs appear is defined as an *operative program* of the system, which is called the operative system (**Figure 9**).

The inputs it receives can depend on the circumstances of the moment or be introduced according to a previously chosen sequence and pre-established means in order for the operative system to produce specific outputs. A succession of inputs – instructive, energy, or instrumental – that allows an operative system to produce specific outputs at the end of internal processes is defined as an *applied programme.* Since the *operative and applied programs* are intrinsically necessary to develop the dynamics of an organized system, [9] must be completed as follows:

dynamics of an open system "S" = [t, I(t), Π(S), P(t, t′), O(t′)] [10]

where Π(S) indicates the existence of programs that give insturctions for producing the dynamics, which can thus be programed to achieve certain states or produce desired outputs within a predetermined time.

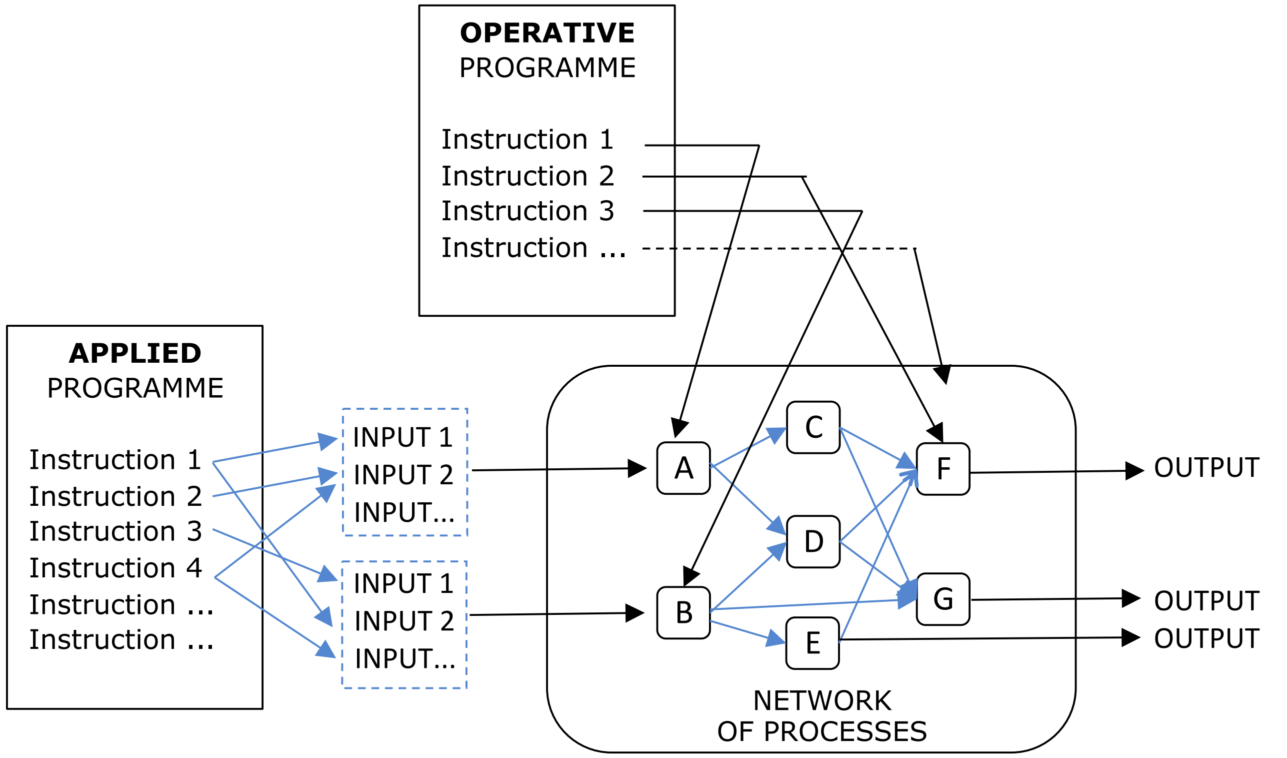

Figure 9 – Operative and applied programmes

Two simple examples will make the distinction clear. I press (apply energy) key P on my computer (instructive inputs) and, thanks to the electrical energy (energy input), the computer carries out internal processes (guided by the operative program) and makes the sign P appear on the monitor (instructive output). I insert a particular blade (instructive input) in the electric meat-grinder. I insert pieces of meat (instrumental input) and press a button (instructive input); the machine carries out internal processes through the consumption of electrical energy (energy input) and minces the meat (transformation), giving out meat in small pieces (instrumental output). To an outside observer, programed dynamics (desired) represent a behavioral objective attributable to an organized system.

The system can be *controlled* if it is possible to impose on it the production of an effective dynamics in conformity with the pre-determined behavioural objective. If we assume that the system has an unvarying organization over time, then the *control* is carried out through the implementation of an *applied programme* that calls for a sequence of inputs – instructive and otherwise – which, with the unvarying *operative programme* assumed, allows the system to produce a *desired* sequence of outputs that represent the *behavioural objective*.

In order for the control system to be able to develop the applied control programme, it must be able to perceive eventual deviations (errors) between objective and actual outputs, so that it can *regulate* the inputs in order for the actual outputs to conform to the desired ones. The control system must thus be equipped with *sensory* organs in order to compare the objective with the actual outputs, and with *effector* organs to carry out the regulation. A system is defined as *instrumental* if it is controlled from the outside for the pursuit of the objectives of some other system for which it is thus an instrument. A *self-controlled*, and not an instrumental, system is defined as a *cybernetic*, or feedback Control System, since it has objectives it pursues by means of a system of self-control (Ashby 1957; Wiener 1961; Johnson et al. 1963; Leigh 2004; Gopal, 2002). The concept of “distance”, or “Error”, is fundamental in feedback Control Systems; in fact, Norbert Wiener, the founder of cybernetics, proposes this concept as the basic mechanism of such a form of control:

Now, suppose that I pick up a lead pencil. To do this, I have to move certain muscles. However, for all of us but a few expert anatomists, we do not know what these muscles are; and even among the anatomists, there are few, if any, who can perform the act by a conscious willing in succession of the contradiction of each muscle concerned. On the contrary, what we will is to pick the pencil up. Once we have determined on this, our motion proceeds in such a way that we may say roughly that the amount by which the pencil is not yet picked up is decreased at each stage. This part of the action is not in full consciousness. To perform an action in such a manner, there must be a report to the nervous system, conscious or unconscious, of the amount by which we have failed to pick up the pencil at each instant (Wiener 1961, p. 7).

For a broad analysis of the different classifications of systems, among which *dynamic* and *control* systems, see Mella, 1982, sections 2.8; for an in-depth analysis of control systems, see Mella, 2014. Of particular interest is the class of *transformation systems*, a subclass of *operational systems*, for which the observer assumes that inputs of some kind are transformed into output through some type of transformation carried out by a transforming device. For more on the many classifications of transformation systems, see Mella, 1982, section 2.9.

17 – The Generalizing Analogical Abstraction. The Scientific Laws

The observer is not content to observe objects, classify them, and conceive of the relations among them needed to create composite objects, groups and systems. After having constructed the observative universe through the technical *descriptions* and divided it into convenient "sections" through appropriate technical *definitions*, the observer can affirm: (i) that the universe is in continual evolution, (ii) that there are differences, at times isolated, at times systematic and repetitive, among the objects whose technical descriptions are included in different technical definitions. In other words, he can observe differences: (a) in the mutual order among the objects of observation relative to space (when the mutual position of the planets changes, so does the way the leaves appear on trees), (b) in the other dimensions of the objects, or more precisely, in their state (for example, when the temperature changes, so does the length of an iron rod or the viscosity of oil), (c) in the admissible *dimensional range* for objects of a given class (whales are *mammals*, even if in terms of other characteristics they do not differ from *fish*).

The perception of systematic differences and of change based on an assumed order represents a form of more advanced observation compared to that of *definition*, and presumes that *grouping* (the differences can be among the objects in the group) and *systematization* (the change can occur in the order of the objects or the order of their dimensional states) have been, or can be, carried out. For this reason, the next step in scientific and operational observation is the activity whereby *laws are deduced*, which involves searching for and identifying in the "observed universe" *regularities* of various kinds among objects in defined groups. The repeated observation of such regularities, corroborated by experiments, though occurring under different observative conditions, leads the observer to *generalize* by carrying out *generalizing analogic abstraction* which lies behind the activity of *deducing laws*, the result of which is the *laws of the observed universe*. A law can be conceived of as the formal representation of an assumed "order" among the objects of observation. In general, a law is a statement that asserts the generality of one or more *relations* among the "dimensions" of objects of observation ("all flat objects with a finite surface also have a perimeter"), among their "dimensional states" ("all red roses have thorns x-millimeters in length"), or among "variations in the dimensional states" ("all chicken eggs solidify according to the parameter S per minute when put into boiling water").

An *empirical law* (or *rule*) is defined as "scientific" if:

– it is formulated in one of the following ways: «Every time "this" occurs, "that" does as well» (variant: If A, then B, always; (x) (y) [Px R P'y]; every time A occurs, B occurs; □ ∀A,□ we observe B, always; A →□B, always; if ∃A, then ∃B, always; B cannot exist without A, etc.);

– it has *empirical* content; without empirical content it can at most represent a formal law;

– it can posit relations among objects belonging to *open sets* connotatively defined and whose extension is not finite or entirely known; thus, these relations are valid not only for the observed objects but for all the objects having the characteristics that define the set, even if they have not yet been observed;

– the relation in question must not derive from conventions or the application of procedures;

– it must be *verifiable* or *falsifiable*; that is, confirmed by favorable cases or positive examples, or refuted by unfavourable cases or evidence, to the contrary;

– it must be *coherent* with other accepted scientific laws and permit *deductions* when included in deductive reasoning.

Scientific laws appear as descriptive and operational models in the *observed* universe, or in broad sections of it, and constitute the basis of the cognitive process called *scientific explanation*, which will be analyzed below in section 19. The *scientist* is an observer who proposes laws to permit scientific explanation. The universe in which it is possible to undertake scientific explanation is one that is "determinable through laws", or *deterministic*.

Scientific laws can be of various types, among which (Braithwaite, 1968):

a. laws of *variation*: these highlight the variations in the states of a parameter over time ("every body on earth is subject to a gravitational attraction that produces an acceleration of 9.8 m/s^2, unless there is a constant k");

b. laws of *covariation*: these connect the variations in the dimensional states observed in objects belonging to the same group ("the width of a butterfly's wings is in relation to the length of its antennae based on the coefficient x");

c. laws of *correlation*: these compare the dimensional states of the same dimension observed in objects belonging to different groups ("the weight of a man's brain is h times that of a dolphin's");

d. causal laws: these highlight the "cause" of given dimensional states ("the characteristic C of the phenotype is caused by the characteristic H of the genotype");

e. functional laws: these reveal the relations among the variations in a dimension (dependent variable) and those of other dimensions (independent variables), without there being a distinct and specific causal relation between the variations in the former and those in the latter ("the speed of a body propelled by a motor in a fluid depends on the power of the motor, according to the factor p, the shape of the body, according to the factor f, and the density of the fluid, according to the factor d");

f. holistic or *systemic* laws: these introduce relations between the dynamics (in a broad sense) of an element of a *structure* and those of the other elements in the same structure; since the structure is unitary, the elements it is composed of are interdependent. Therefore, the dynamics of an element cannot be simply related "causally" or "functionally" with those of the others, since it is impossible to isolate the behavior of any element without at the same time considering that of all the remaining elements. *Holistic* laws analyze the interdependence among the variables that characterize the "entities" of a system ("the functioning of a heart depends on that of the lungs; but the functioning of the lungs depends on that.... of the heart"; "the number of hares depends on the number of predatory eagles; but the number of predatory eagles depends on that... of the hares they feed on"; the demand for products depends on the income families have to "spend" on purchases; the income available depends on the number of workers employed in productive activities; the number of workers employed depends on the production needs; these needs depend...on the demand for products");

g. *probabilistic*, or *stochastic* laws: these indicate the probability certain dimensional states will occur ("in a population of rabbits that feed on lettuce, there is a 70% probability of rabbit kitten quintuplets");

h. *teleological*, or *intentional* laws: these derive mainly from the observation of biological phenomena; they correlate the states of some observable object assumed to have "objectives" or "goals" – or, in general, *intentions* – with some biological subject ("birds build nests to protect their offspring"; "individuals participate in production to satisfy their economic goals"; etc.).

The opinion is widespread that scientific observation must search for *causal laws* which, it is often stated, are the only ones that can offer suitable "explanations" of the observed universe. Laws of this type have been, and still are, extremely useful in the advancement of many fields of science; but it is equally clear that along with the *causal* laws there are also other types which are not reducible (or not easily reducible) to causal laws. In studies on social behavior, in economics in particular, together with causal laws we find *functional* laws, which often are more significant, and above all *holistic* or *systemic* laws, the only ones often capable of providing satisfying "explanations" of the dynamics of biological and social systems.

18 – Scientific Theories

After the general relations among objects of various groups have been identified through the formulation of *scientific laws*, *observation* attempts fo reach an "explanation" and a "forecast" of the states of the entire *observed universe*. The scientist thus tries to systematize the identified regularities, seeking out the interrelations among the individual laws to form a "unitary body of laws" that can provide increasingly broader and more complete explanations of the phenomena open to observation. However, the scientist does not limit himself to accounting for what is observable but also tries to anticipate, where possible, the determination of given phenomena which has not yet been observed or to take account of observable phenomena whose occurrence is assumed to be linked to other, non-observable phenomena. This gives rise to *scientific theories*; that is, interconnected and coherent formalized systems of hypotheses used to justify the existence of and connection between "laws" to form a unitary descriptive and predictive *body of laws.*

Theories (like individual laws) can be interpreted as *formal hypothetical models of the observed universe* aimed at describing, explaining and predicting the behavior of that universe. Theories are more advanced models of the individual "laws". Even if they include laws or allow us to derive laws, they are not mere formalizations of observed regularities but represent *conjectures*, or *hypotheses*, that explain the occurrence of those regularities. Theories are often produced even before observation occurs; the "theory of relativity" is not a simple law but a conjecture on the functioning of the physical universe, and many facts that conform to the theory have been observed many decades after it was posited.

In any event, since it is a model, a theory can never be defined as "true", but at most as "reliable". Inversely, it can be considered "false" when it does not conform to the observable facts beyond any reasonable doubt, in which case it must be replaced by another theory. Even if a theory can never be ascertained to be "true" or "verifiable" – even if it can be "corroborated" by facts that support its validity – it must nevertheless be "falsifiable". The present study itself is nothing other than a theory of observation; it is up to the reader to attempt to falsify or corroborate it with appropriate examples. A conjecture that is not falsifiable with some instrument of proof becomes a "dogma", which cannot become part of science (Popper, 1959, 1963).

An inductive generalization can never be ascertained as true since, if N is the number of cases in which the generalization has been verified, no matter how large N is with respect to the infinite number of possible cases, the mathematical probability the generalization would be true is zero. On the other hand, a theory can always be declared "false" since, if theory T must predict or explain case C, then

if T then C under conditions E

implies that if T is true, then C must occur; if C does not occur, then T is not true, or the conditions E did not exist. From a logical point of view, even if T is false, C could nevertheless occur.

A question immediately arises: why does the scientist conceive of theories to explain and predict the observed reality? Science is useful in satisfying man's innate need for explanations, his curiosity that feeds his scientific cognitive behavior. Why do the sun and moon rotate around the earth while the stars appear to be immobile? Why, during thunderstorms, do thunder and lightning occur? How can birds fly? It is plausible that the search for an answer to such questions pushed man to undertake scientific research not subordinate to immediate operational advantages.

A second answer is that science is useful for man in his *operational behavior* toward reality; how can man *operate* effectively and efficiently if he does not know the laws that regulate (or, better yet, are assumed to regulate based on some theory) phenomena in the universe? Why does a spike of wheat grow when we plant a seed of grain? Why, when we fertilize the soil in which we have planted a seed, a more robust and abundant spike of wheat grows? Why can fire melt some rocks to produce a harder and more resistant material than the rocks themselves? How can we measure the surface area of a field lying over an undulating hill? These are probably the types of questions that have motivated the search for the explanation of phenomena, which has led to *scientific* observation. For many millennia no one was able to provide a chemical explanation for fertilization, the physics of fusion, the rules of trigonometry, or the laws of astronomy; however, operational needs together with repeated observations laid the observational groundwork for the first scientific laws.

In conclusion, beyond the gratification of the cognitive motivations of individual scientists, beyond the gratification, in terms of prestige, of the scientific community, scientific research allows two socially useful objectives to be achieved: first, to gain knowledge for *speculative* purposes regarding scientific cognitive behavior and, second, to gain knowledge for *operational* purposes regarding *operational* cognitive behavior.

In other words, on the one hand, science *explains* and *predicts* the objects in the universe, and on the other indicates the rules for effectively and efficiently "producing" certain objects in the universe. If the objective of "science" is to explain "reality", since the latter, being multi-dimensional, is "too" complex to be globally analyzed (at least using the instruments that are available today) various specialized sciences have developed, each of which sets forth laws and theories regarding a specific *observed universe*. Each "specific science" focuses on a particular *observative universe* and investigates the relative *observed* or observable *universe*. When the specific science observes objects already analyzed by other sciences, it considers them based on different dimensions.

19 – Scientific Explanation and Prediction

The explanation is a process of guidance toward the construction of a model from which those phenomena or events could derive.

Any kind of scientific statement, concept, law, and any description of a phenomenon is a model construction which tries to reflect phenomena of the external world. Reality is extremely complex; it consists of strongly or more weakly related events. Science makes an attempt to separate and isolate different effects and phenomena. It seeks the simplest relationships by which examined phenomena can at least be described or demonstrated. It creates simplified models which only partly reflect reality, but which allow contemplation, and what is most important, pragmatic, even if sometimes modest, predictions (Csányi 1966, p. 148).

"Explaining" a phenomenon F (termed the *explanandum*) means constructing a succession of statements, that is, using deductive *argumentation*, E(n) (termed the *explanans*), to obtain F as a *valid* conclusion. The explanation process is normally recursive and presents the following structure:

F because E(n),

E(n) because E(n-1),

E(n-1) because E(n-2),

…

E(0).

End.

The explanation process is "closed" when we reach E(0), that is, an explanans with no further explanandum, which I define as the *operational closure* of the explanation. E(0) represents the *point of ignorance*, the limit to knowledge, and it can denote two possible forms of ignorance:

a) E(0) = "*That which is not yet known*". This represents *reversible ignorance*, which can take the form of: (i) *temporary ignorance* ("Research in progress …", "We are checking", etc.); (ii) *disinterest*, that is, dissatisfaction with E(1) ("I'm not interested", "Enough already!"); (iii) *secretiveness*, that is, the desire to hide knowledge ("I can't explain it to you").

b) E(0) = "*That which we can never know*". In this situation, operational closure represents *irreversible ignorance*, which can take various forms: (i) *permanent ignorance*, which reveals itself to be incapable of ever being known (Heisenberg's indetermination principle, Gödel and Turing's theorems, and others that are similar); (ii) the *mysterious*, which is the unknowable (ineluctable principles, myths, God, metaphysics or agnosticism, acts of faith, etc.); (iii) the *postulate*, that is, a non-demonstrable, assumed origin from which to derive the explanation ("We hypothesize that ...", "Given that ..."; "We assume that …", etc.); (iv) *chance*, in all its manifestations (quantum randomness, genetic mutations, initial impulses of combinatory systems, etc.); (v) *necessity*, or the self-sufficiency of E(0) ("It must be like this", "It can't be otherwise", "The immobile engine", etc.). In these cases operational closure is an *explanatory dogma*.

We can come up with several explanations for the same phenomenon.

A – *Common Sense, Simplistic, Descriptive or Contingent Explanation*. These are the explanations we daily apply to justify some phenomenon or to answer some question without recurring to scientific laws and theories and without making use of sophisticated qualitative/quantitative models (Hempel. 1965), but relying on *intentions* ("The light has come on because Aldo had to go into the garage"); *chance* ("I met Aldo because he happened to be passing by"); *experience* ("It's raining because I went out without my umbrella"; "He got a fever because he was bit by an insect"); and *regularity* or *common sense* laws ("It's raining because the sky is full of clouds"; "This is a rainy spring because the winter was dry"; "He got into an accident because he was drunk", "… because he was unlucky", etc).

B – *Classical Scientific Explanation*. The classical explanations are those that are used in any scientific context where the explanans is a model (Cupples. 1977) which, in addition to the initial conditions of the phenomenon to explain, C, also includes the causal laws or functional relations, L, as well as the scientific theories or assumptions that can take into account the explanandum, according to the following schema:

EXPLANANS	→ T = scientific theories and postulates, & L = scientific laws, & C = initial conditions.
EXPLANANDUM	→ F = phenomenon to explain
CONCLUSION	→ F is observed *because*, given the initial conditions, C, it follows from the laws L, if we accept theory T
OPERATIONAL CLOSURE	→ The fundamental theories and postulates represent the operational closure of the explanation.

Seventy years ago Carl Hempel and Paul Oppenheim published an essay, *Studies in the Logic of Explanation*, which was truly epoch-making. This 1948 article provided the foundation for the old consensus on the nature of scientific explanation that reached its height in the 1960s (Salmon, 1990 p. 3). This form of explanation has become recognized as the scientific explanation par excellence (Braithwaite, 1968).

C – *Procedural Explanation*. The procedural is a very common type of explanation, even though it has not received proper attention in the literature. It is used whenever a phenomenon (the square root of Y is ?) does not derive from a particular model but rather appears to be the result of some elaboration or calculation, or the application of some algorithm, procedure or program (Gibbon. 1998). When we ask ourselves why the solution to extracting the square root of an expression does not correspond to the answer in our textbook, why our ticket was not drawn in the lottery, or why we ran into the bumper of the car in front of us, we must look for the answer in the procedure followed for the calculation or lottery drawing, or we must examine our parking attempt. The procedural explanation always appears very convincing because not only is it the logical conclusion from the premise, it also allows us to reconstruct and emphasize the factual procedure (the logical or physical process) by which the conclusion emerges from (is produced or determined by) the premises. In my opinion, one of the most well-known and powerful procedural explanations is the Theory of Evolution, in which Darwin (1859) sets forth the "natural", biological and environmental laws that give rise to a procedure (process) that allows populations and animal and plant species to evolve over time (Mella and Beretta, 2018).

D – *Systemic explanation.* The systemic explanation must be used when the explanandum cannot be reduced to a model that includes laws and theories (classical explanation) or results from the application of a procedure; instead, it must be considered a phenomenon connected to the dynamics of some system process whose model the scientist is trying to uncover. The systemic explanation must highlight the processes, P, that have generated F, which depends on the systemic structure, S, that supports those processes, the programs that guide the latter, and the environment, E, that conditions them (Mella. 2012). The systemic explanation is thus more powerful, as it can take into account and justify any phenomenon whatsoever, from global warming to population dynamics, the deviation of the route of a space probe to the spread of epidemics (Mella. 2014a).

E – *Teleological explanation.* The systemic explanations can be integrated by the teleological explanations, which try to take into account the behavior of a system with an objective (usually a biological one) by using the notion of "goal" or "objective" (Lennox. 1992). The basic line of argumentation is to subsume biological "goal-directed" systems under the broader category of "directively organized" systems, which can apply to both living and inorganic systems (Plamondon, 1979, p. 153). Precisely to the extent it is a science of guidance and communication, *cybernetics* today is mainly associated with the control of machines and mechanical systems. None other than Ludwig von Bertalanffy, considered to be the founder of General Systems Theory, recognized that:

[A] great variety of systems in technology and in living nature follow the feedback scheme, and it is well-known that a new discipline, called Cybernetics, was introduced by Norbert Wiener to deal with these phenomena. The theory tries to show that mechanisms of a feedback nature are the bases of teleological or purposeful behaviour in man-made machines as well as living organisms and in social systems (von Bertalanffy, 1968, p. 44).

From these simple considerations it follows that:

i. explanations can proceed in several different directions;
ii. they can rely on different kinds of laws or procedures;
iii. no explanation is completely satisfying only in terms of the structure of the explanatory argument; it is necessary to specify the cognitive objectives the explanations seek to achieve;
iv. as with any other type of argumentation, explanations require ability in the subject, both in terms of valid and exhaustive premises, which constitute the *explanans*, and a general reasoning capacity; that is, the ability to grasp the deductive relations among the premises and conclusions.

The best explanation is the one that best satisfies the need for the individual or scientific community to take account of the explanandum. It is unlikely anyone would turn to physiological or psychological theories and laws, or to logistical processes, to explain "why there is no more mayonnaise in the fridge". While the classical explanation is particularly useful in the context of the experimental sciences, systemic explanation can also be used to explain individual, non-repeatable events involving unique facts deriving from a system's behavior. Brought to mind are the words of Dixon and Emery, who warn against tautological scientific definitions:

When asked, for example, what happens to two blocks of copper initially at different temperatures left alone together in an insulated container, they will all reply that the blocks will come to the same temperature. Of course, if asked how they know, they usually say "Because it is a law of nature."… [T]he opposite is true…it is a law of nature because it happens (Dixon, 1965, p. 428).

"Prediction" has the same formal structure as "explanation", the difference being that the premises temporally precede the conclusions. The "scientific explanation" states: "phenomenon F has these and these other characteristics because conditions C exist and laws L and theories T are valid". "Prediction" instead states: "since laws L have been observed, and given that we can assume the validity of theories T, when the conditions C occur, phenomenon F will also occur with these and these other characteristics".

While the quality of the explanation depends on the degree of confirmation the premises offer regarding the conclusion, the quality of the forecast depends, conversely, on the degree of confirmation the conclusion offers with regard to the premises. Thus, scientific and systemic explanations are preferred, since such argumentative structures are held to be the best in also providing accurate forecasts regarding the occurrence of F.

Often an explanation is not possible in a given observative universe since the scientist has excluded from the universe vector U(N), defined above in [1] of section 4, those dimensions that could offer a satisfying explanation. In such cases it is necessary to forego any explanation or to accept explanations from other sciences or disciplines that have the significant dimensions in their U(N). Thus, the economist can try to explain the effects of war expenditures on economic growth and inflation, but only the biologist, sociologist, psychologist (often the psychiatrist as well), or historian can attempt to explain why man is an "aggressive" being.

In many circumstances, a realistic approach must be followed. In their so-called "realistic" conception of knowledge, Stephen Hawking and Leonard Mlodinow recognize that all we can know about "reality" consists of networks of world pictures, or general models, expressed even through mathematical language:

In the history of science we have discovered a sequence of better and better theories or models, from Plato to the classical theory of Newton to modern quantum theories (Hawking and Mlodinow, 2010, p. 8).

The explanation becomes unequivocal only when progress in the scientific field leads to one operational closure prevailing over the others. Multiple, equally valid, world pictures exist; therefore, science requires multiple models to encompass existing observations:

Like the overlapping maps in a Mercator projection, where the ranges of different versions overlap, they predict the same phenomena. But just as there is no flat map that is a good representation of the earth's entire surface, there is no single theory that is a good representation of observations in all situations ... (Hawking and Mlodinow, 2010, p. 10).

20 – The Systems Thinking Approach to Explanation and Understanding

In order to understand and explain reality, *Systems Thinking* and *System Dynamics* approaches, applied jointly, allow us to produce the best systemic explanations through the construction of systemic models and the simulation of their operation (Mella, 2012). Systems Thinking is a cognitive discipline presented by Peter Senge in his book The Fifth Discipline: the Art and Practice of the Learning Organization (Senge. 1990). Other terms can also be used to indicate this new way of thinking. Barry Richmond, one of the most renowned experts in this discipline (he was the founder, in 1984, of the High Performance System) stated:

Systems Thinking, a Systems Approach, Systems Dynamics, Systems Theory and just plain "Systems" are but a few of the many names commonly attached to a field of endeavor that most people have heard something about, many seem to feel a need for, and few really understand. […] As I prefer the term "Systems Thinking," I'll use it throughout as the single descriptor for this field of endeavor (Richmond, 1991, p. 1).

Systems Thinking is a Paradigm and a Learning Method. The first conditions the second. The second supports the first. The two parts form a synergistic whole (Richmond, 1994, online).

According to Systems Thinking, in order to *explain* and understand reality we must represent it in terms of dynamic, repetitive and interconnected systems; objects observed from a static vision, non-repetitive systems, individual phenomenon, simple causes, simple effects, a lack of memory: these are the errors Systems Thinking tries to eliminate. The dimensions that make up the *observative universe* of the systems thinker are composed of variables, V_n, of all types, and of relations, R_n, between each variable and the others:

$U(N) = [V_1 \leftrightarrow R_1, ..., V_n \leftrightarrow R_n, ..., V_N \leftrightarrow R_N],\ M>1$

Systems Thinking is based on the following simple general principles (Mella. 2012):

Holonic vision. Every observable object (galaxies, planets, organisms, cells, quarks) must be interpreted as an element composed of parts and, in turn, as part of a larger group (Koestler, 1967, 1978; Wilber, 2000, 2001); similarly, Systems Thinking teaches us that every system is composed of sub-systems which are part of a super-system (Mella, 2012).

Systemic vision. Each event, phenomenon, datum, quantity, quality, number, etc., must always be observed, conceived and interpreted as an input or output of a process that is part of some dynamic system, the map of whose structure and processes must be constructed. We must avoid simplistic causal explanations, which explain phenomena in terms of causes, or simplistic functional explanations, which explain outputs as a function of inputs.

Structural vision. Every phenomenon is derived not from causes or inputs but from a process that depends on a structure, and thus on an organization, or on stable relations that act according to a program. To understand a phenomenon, we must reconstruct the structure that it triggers, if it is an input phenomenon, or from which it is generated, if it is an output phenomenon.

Circular reasoning. In order to understand a phenomenon linked to a system, we must go beyond the linear logic of the cause-effect relationship and follow that of systemic interdependence and multiple loops: every output of a dynamic system derives from a multiplicity of inputs and directly and indirectly represents, to a greater or lesser degree, future inputs.

Circular reasoning allows us to make our *explanation* more efficient since:

a. it obliges us to consider the circular relations among phenomena, the interconnections among processes and systemic structures, and does not limit ourselves to considering only the immediate interdependencies but encourages us to verify the existence of other interconnections;

b. it requires that we specify the point of view of our observations; every phenomenon is an input or output of a system according to our point of observation;

c. it forces us to consider our own actions as elements in a system of interdependent decisions; we must never forget that we are cognitive systems and that our behavior depends on the entire state of knowledge; a state that, however, is modified precisely as a result of our own actions, thereby initiating the process of learning from experience;

d. it obliges us to reflect on the causes of our behavior, making us aware that the effects of today's actions can be a motivation for tomorrow's actions and that we are not only spectators but also actors with regard to the events that befall us.

System Dynamics is a discipline and technique that unquestionably goes back to Jay Forrester and his fundamental book Industrial Dynamics (Forrester, 1961). In recent works, Forester defines Systems Dynamics as follows:

System dynamics combines the theory, methods, and philosophy needed to analyze the behavior of systems not only in management, but also in environmental change, politics, economic behavior, medicine, engineering, and other fields. System dynamics provides a common foundation that can be applied wherever we want to understand and influence how things change through time. The system dynamics process starts from a problem to be solved—a situation that needs to be better understood, or an undesirable behavior that is to be corrected or avoided. The first step is to tap the wealth of information that people possess in their heads. [. . .] System dynamics uses concepts drawn from the field of feedback control to organize available information into computer simulation models (Forrester, 1991, p. 5).

21 – Communication. Signs and Languages

The preceding sections have analyzed observative activities under the assumption these were carried out by a single individual during "private" mental activities; that is, we assumed an isolated subject who did not communicate the results of these activities with others. Let us now abandon this hypothesis and assume the individual is part of groups of individuals of varying size. To exchange the results of their observations, the individuals must undertake communication processes by using signs organized into languages.

"Communicating" means "making commonly available", through a process of transmission, various thought content. Thus, the communication requires at least two subjects, one of whom – the transmitter (T) – wants to transmit to the other, the receiver (R), a certain thought content in the form of a message. As common experience reveals, to achieve any type of communication, T must produce some *sign* with significant content and transmit this to R by using some *communication channel* through which the transmitter's *signs* – if necessary, translated into different signs, or *signals* – are sent to R, who must interpret them; that is, understand the information content to make sense of the message in order to acquire the thought content T wanted to transmit.

Apart from telepathic transmissions, the *signs* therefore represent the essence of every communication process. But what are signs? How can they serve as indicators of T's thought content? What are the properties that enable R to elicit the thought content of T? How do signs become languages? Generally speaking, we can define a "sign" as any deformity (difference) that is observable (or assumed) in relation to any observed (or assumed) relative uniformity (or regularity). The black line on a white sheet of paper and the plume of smoke on the horizon are both signs, as are a reduction in the general price index and the increase in the unit cost of production in a given month. Some signs are "natural" (the swallow appearing in the sky is a "natural" sign of the arrival of spring).

Signs can serve as instruments of communication since they possess *meaning*, or *significance*: they are able to designate thought content, whether in the form of objects of observation (Piero), their dimensions (academic degrees), states (degree in Economics and Business), technical descriptions (the black pen, the Montblanc brand, bought yesterday for 500 euros), technical definitions (the man, the pen, the demand curve, the company, red), or even imaginary objects (Dante's Inferno, the Hippogriff), which are not observable but represent thought content. We indicate by "objects of discourse" the set of what that can be communicated; therefore, the set of objects of discourse is more powerful compared to the objects of observation.

It is useful to recall Ferdinand de Saussure, for whom "*The linguistic sign unites, not a thing and a name, but a concept and a sound-image*" (Saussure, 1916, p. 66). I shall define *denomination* as the process by which a sign (a conventionally accepted name, in particular) is assigned to a concept.

Some people regard language, when reduced to its elements, as a naming-process only – a list of words, each corresponding to the thing that it names. ... This conception is open to criticism at several points. It assumes that ready-made ideas exist before words; it does not tell us whether a name is vocal or psychological in nature ...; finally, it lets us assume that the linking of a name and a thing is a very simple operation – an assumption that is anything but true. But this is a rather naive approach [...] The linguistic sign unites, not a thing and a name, but a concept and a sound-image. The latter is not the material sound, a purely physical thing, but the psychological imprint of the sound (Saussure 1916, pp. 65, 66).

More specifically I shall define "denomination" (or "semiotic code") as the "convention" through which, in a given social context, we attribute meaning to a sign "*S*". There are three basic forms of *denomination*:

a) *Proper denomination* matches a *sign* to a *technical description* of a single object "O"; that sign *S* then becomes the *proper name* of the *described* object, the only one which can be denoted by that description and which represents the *signified* of S; for example, Piero Mella.

Proper denomination of [*S* denoting "O"] = [des O]

b) *Intensive common denomination* matches a sign to a *technical definition*. That sign becomes the *common name* for all those objects, denotable by that definition, which constitute the *signified* of *S*, for example, a teacher.

Intensive common denomination of [S denoting O*] = [def O*]

c) *Extensive common denomination*, which explicitly indicates all the K objects that can be denominated by *S*.

Extensive common denomination of [S denoting O*] = [des O^1, ..., des O^K] .

We shall define the *meaning*, or *significance* of a sign as the set of objects of discourse that can be *denominated* by that sign in the context of a group (or social context). The signified is thus conventional and refers not to the "indicated objects" but to the "indicator signs" that denominate the objects of discourse. However, the *significance* does not reside either in the indicator sign or in the indicated objects, but in the "mind" of the subjects that use it; it is always attributed in *conventional* form.

The *set of signs* that indicate the same set of "indicated objects" represents the *signifier* of the sign and, like the *significance*, it is conventional. Every *sign* "belongs to" a *signifier* and "has" a *significance*. Therefore, every sign that is part of a *signifier* indicates any of the corresponding *signified*. Conversely, any element of a *significance* can be indicated by any sign of a corresponding *signifier*. The correlation between a *signifier* and a *significance* carried out in the *code* represents a "*seme*"', which is the basic semiological unit; *semantics* is the branch of *semiology* that studies the formation of "semes", that is, the rules for correlating "signifieds" and "signifiers" (Putnam, 1975).

We shall refer to *language* as a system of "intentional signs" belonging to the same *universe of signs*, through which a subject can try to communicate *any thought content* in a given community. Every *language* can be considered as an instrument for communication. The *fundamental role of languages*, whatever their form (written, spoken, gesticular, using mime, ritualistic, iconic, etc.) is to permit *communication* among people; that is, the transmission of thought content between the transmitting subject and the recipient. The main types of thought content for communicating through language – for which it is assumed the process for denominating signs is known – are varied. Nevertheless, the following are fundamental:

1. *expressions of judgments* and *emotions*, understood also as expressions of opinions and evaluations, impressions, indications of kindness, beauty, amazement, annoyance, happiness or unhappiness, and so on ("What a beautiful rose!");

2. *declarations of intentions* to undertake certain actions or types of behavior, positive and negative ("I want to pick the rose before it withers");

3. *orders*, understood as manifesting a desire, or a necessity, to a subject that he behave in a certain way ("You go pick the rose, but be careful not to leave the stem too short");

4. *questioning*, expressed as requests for thought content and answers ("Should I also pick

the tulips?");

5. *answers to questions* and *orders*; that is, the revelation of thought content that has been requested ("Ok. I'll go then and pick the rose"; "No, leave the tulips where they are");

6. *descriptions* and *procedures*; that is, the results from observing objects and portions of reality and the procedures for obtaining certain objects as the result of the application of the rules established by the procedure;

7. *information* or *specific data* useful in carrying out operations or activities;

8. *argumentation*, through which the cognitive unit tries to judge the truth of certain statements (answers, descriptions or information) and seeks the explanation of the phenomena observed (Tindale, 2006).

[U]ntil recently, pragma-dialectical analysis tended to concentrate on reconstructing primarily the dialectical aspects of argumentative discourse. It is clear, however, that the analysis and its justification can be considerably strengthened by a better understanding of the strategic rationale behind the moves that are made in the discourse. For this purpose, it is indispensable to incorporate a rhetorical dimension into the reconstruction of the discourse (Eemeren, van, Houtlosser, 1999, p. 164).

9. *procedures,* or sequences of operations to undertake to carry out a given type of behavior.

Every language has a *vocabulary* (lexicon), a specific *syntax* and *praxis* which must be known to correctly use the language for communication. The *vocabulary* provides the *linguistic definitions*, which represent the procedure for determining (therefore: with the maximum possible, admissible and appropriate precision possible) the meaning of the signs of a language. It is useful to distinguish between two procedures for *linguistic* definitions (Harris and Hutton, 2007):

a. *denotative* or *extensive* definitions: these attribute meaning by expressly indicating all the objects of discourse (the denotation of the sign) that can be denotated by the sign (for example, a businessman is someone who produces goods and services, or undertakes marketing, banking, insurance, and transportation activities). The objects of discourse thus indicated represent the *extension* of the sign. Among the *denotative* definitions, of particular significance are the *literary* ones, which, in fact, represent the *linguisitic apparatus* that translates a given technical definition into the signs of a literary language (Italian, for example);

b. *connotative* or *intensive* definitions: these attribute meaning by indicating the characteristics (the *connotation* of the sign) that can, or must be, found in the objects indicated by the sign and that represent its *intension* (for example, a businessman is someone who organizes work for the purpose of production, independently of the profit aim).

Depending on the type of objects that make up the "signified" universe, we can divide definitions into three categories:

1) *lexical definitions*: these provide the meaning of a sign that is used correctly in the language common to individuals and that already has its own meaning – intensive or exensive – which must be clarified;

2) *stipulative definitions*: these provide the meaning of a sign that is invented ex novo, or of a sign to which, in a certain propositional context, we wish to attribute a specific meaning;

3) *clarifying definitions, or re-definitions*: these specify, through different signs, definitions already formulated with the use of certain signs; they give different interpretations of signs that are already significant.

We must keep separate these three types of definitions since, quite often, it is necessary to attribute a "judgment about the appropriateness" of the definition of a given term. Since *intensive* lexical definitions regard signs already having an actual meaning, we can observe whether the new *intension* corresponds to the *extension* of the sign or to another extension. In the first case, the definitions are *correct* (exact, well-formulated); in the second case they are *incorrect* (wrong, badly formulated). On the other hand, a *stipulative* definition can never be judged to be correct or incorrect, precisely because it provides the meaning of a term *ex novo*. At most, we can say it is appropriate or not, acceptable or not, in relation to the objectives of the communication. Clarifying definitions can include those referred to as *theoretical* or *analytical*, which aim at specifying in a technical manner the *meaning* of a sign that must be used unambiguously in scientific reasoning with an incontrovertible meaning.

The operation of *definition* attributes meaning to signs; the opposite operation, which identifies the meaning previously attributed to a sign, is termed *interpretation*. *Definition* and *interpretation* are the two basic moments in the communication process. In fact, a communication process is successful if R, through a correct *interpretation*, can understand from the signs the *message* sent by T. In general, the communication process is successful when R, through the signs (signals) received, is able to shape similar thought content to that which T intended to transmit. The minimal conditions for successful communication are the following:

1. T must be able to transmit signs (or signals) that form a message with immediate significance for R;

2. R must be able to perceive T's sign;

3. R must be able to interpret the perceived message to understand the real meaning behind it;

4. the real meaning attributed to T's message must coincide with R's interpretation of it.

Since communication usually occurs in the context of a given social group, its success is also conditioned by the *context* in which it takes place, by the roles played and positions held by T and R within the group, and, naturally, by the *personal equation* of the two subjects.
It is useful to note that the phonologist Roman Jakobson (1970, pp. 213-222) analyzed the functional aspects of linguistic acts in the context of the communication process, distinguishing among:

1. the "expressive" or "emotive" function;

2. the "conative" function, expressed in its purest grammatical form in the vocative and imperative case,

3. the "phatic" function, that serve essentially to establish, extend, prolong or interrupt communication;

4. the "metalinguistic" function, when the sender and/or recipient of a message deem it necessary to check whether or not they are properly using the same code;

5. the "poetic" function;

6. the "referential" function, when we want to communicate contextual facts, or "states of the world".

It is not difficult to relate these six functions to the eight types of thought content that can be communicated (see pag. 44).

Language can also be used *pragmatically* (phatic function) even simply for ceremonial aims ("Good morning", "Welcome", "Pleasure to see you", etc.), and can carry out a selfreferencing function by indicating to the receiving subject that the sender wants to start, continue or stop communicating with him ("Hey!", "What rainy weather", "Over and out"). Language can be pragmatically also used to convince someone to "do something" or to achieve results or objectives. For example, the sign "stop" written in words or on a sign at the end of the street, the sign "Come at 9 a.m.", or the sign "I understand. I'm coming" clearly are sent to produce or declare the effects of behavior and they produce or declare the effects of behavior if the meaning of the sign is recognized by those receiving it. This ability of signs (and thus of languages) is knows as *performativity* (Bial, Schechner, 2004) a term introduced by John Langshaw Austin, a language philosopher who has studied the pragmatic effects of signs and languages.

Utterances can be found, satisfying these conditions, yet such that
A. they do not 'describe' or 'report' or constate any thing at all, are not 'true or false'; and
B. the uttering of the sentence is, or is a part of, the doing of an action, which again would not normally be described as, or as 'just', saying something. …
Examples: (E. a) 'I do (sc. take this woman to be my lawful wedded wife)'—as uttered in the course of the marriage ceremony. (E. b) 'I name this ship the Queen Elizabeth — as uttered when smashing the bottle against the stem. (E. c) 'I give and bequeath my watch to my brother — as occurring in a will. (E. d) 'I bet you sixpence it will rain tomorrow.'
[…] None of the utterances cited is either true or false … What are we to call a sentence or an utterance of this type? I propose to call it a performative sentence or a performative utterance, or, for short, 'a performative'. The term 'performative' will be used in a variety of cognate ways and constructions, much as the term 'imperative' is. (Austin, 1962, pp. 5-6.

It is worthy of note that, as I am told, in the American law of evidence a report of what someone else said is admitted as evidence if what he said is an utterance of our performative kind: because this is regarded as a report, not so much of something he said, as which it would he hear-say and not admissible as evidence, but rather as something he did, an action of his. This coincides very well with our initial feelings about performatives (ibidem, p. 13).

A particular very important function of language is the rhetorical one with which one tries to persuade another subject on the correctness, goodness, opportunity of given opinions.

David Zarefsky puts it, "Rhetoric may be taken to be the study of the process of public persuasion. It is the study of how symbols influence people" (cited by Schiappa, 2003, p.4). Today the term rhetoric is used to designate two different sorts of practices: specific acts of persuasion, such as a public oration, as well as the analysis of such acts (ibidem, p. 4).

22 – Argumentation and Fallacies (Elementary Introduction)

A fundamental function of language, as we have seen in the preceding section, is to transmit thought content. Of primary importance here is the *argumentation function* for transmitting opinions about the truth or falseness of a declarative proposition, or statement, which is a sequence of basic signs capable of expressing a thought content that can be ascertained to be "true" or "false" using some conventional procedure, formal or informal.

In general, a *statement* is a sequence of propositions aimed at expressing definite thought content (expressions, orders, questions, information, arguments) and, in a broader sense, even the meaning of that sequence of propositions.

Inference is the process through which an *argumentative statement* ("argumentation" or "argument") – in the form of a compound statement – seeks to demonstrate the truth of given explicit opinions contained in a specific statement (Foss, Griffin, 1995; Eemeren, Van, Houtlosser, 2005). Therefore, *argumentation* is a particular statement consisting of a variety of correlated propositions through which: (i) a proposition is stated to be "true" or "false", (ii) as a function of the "truth" or "falseness" of the others, (iii) taking into account the logical or factual relations that bind them. The proposition whose "truth" or "falseness" is asserted is called the *conclusion* of the argumentation; the others are the *premises*.

We know that every statement is either true or false. Therefore we say that every statement has a truth value, where the truth value of a true statement is true, and the truth value of a false statement is false. Using this concept, we can divide compound statements into two distinct categories, according to whether the truth value of the compound statement is determined wholly by the truth values of its components, or is determined by anything other than the truth values of its components (Copy and Cohen 2008, p. 290).

The conclusion "derives" from the premises if, the premises being true or false, even the conclusion can also be deemed true or false, on the condition the argumentation is *valid*, or *correct*. This means that by making certain *hypotheses* about the "truth" (or the "falseness") of the premises, it is possible to *determine* the "truth" (or "falseness") of the conclusion. While "truth" and "falseness" are attributes of propositions, "validity" ("correctness") and ("invalidity" ("incorrectness") are attributes of argumentations (Tindale, 2004, 2006). If an argumentation is correct and based on premises *ascertained* to be true, then the inference is "valid" or "correct".
Using the symbols examined above, let us suppose that a declarative proposition, E, transmitted from Alfa to Beta in a given language, asserts that the state: $d_n(A^*) \in [\text{def } A^*]$ is *true*; for example, "Snow is white" states that:

$$[\text{def } A^*] = [\text{def "snow* "}] \text{ includes: } \quad d_n A^* = [\text{"color snow* = white"}].$$

The proposition "Snow is white", composed and transmitted by Alpha**,** is *true* for Beta if the latter can, *using his own procedure* (which is not necessarily similar to that used by Alfa), *construct* $[\text{def } A^*]$, thereby *determining* $d_n(A^*)$ and verifying it belongs to the definition; otherwise the proposition is *false*. This is the meaning of Alfred Tarshi's rule for truth: "*'Snow is white', is true if and only if snow is white***"** (Tarski, 1944, p. 342).

But one might object that, ultimately, truth is a matter of using and accepting a sentence as an adequate description of a state of affairs. Thus, "Snow is white" is true if and only if we are prepared to use and accept that sentence to describe a property that snow in fact has. "Snow is black" is a misassignment; it is false, because we are not prepared to use and accept that sentence as a description of snow [more correctly: a description of a dimensional state of any object we denote as "snow" (author's note)]. But with "Snow is marble" we may begin to hesitate; perhaps in certain circumstances, it is a true metaphorical description (Ankersmit and Mooij, 1993, p. 78).

Alfa's statement to Beta that $\Delta d_n(A^*) \in [\text{def } A^*]$ ⊂⊂⊂ (for example, "men are mortal") or that $[\text{des}(A^m)] \in [\text{def } A^*]$ (for example, "Piero is a man") is *true* if Beta is able to undertake a cognitive procedure that can construct $[\text{def } A^*]$, that is, "man", and can recognize that $\Delta d_n(A^*)$, that is, "mortal", belongs to it and identify $[\text{des}(A^m)]$ = Piero as an element of $[\text{def } A^*]$. In conclusion, the statement "Piero is mortal" is *true* if [des PIERO] ⊂ [def MAN*] and $[\Delta d_n(A^*) = \text{"mortal"}] \in [\text{def MAN}]$. The statement "The fourth root of 100,000 is 17,7827941" is true if the [def SQUARE ROOT] includes a calculation procedure that, when applied, provides the declared value.

Since the statements used to construct a line of reasoning are expressed through a language, the truth or falseness of a statement implies that we are able to interpret it in a known language. Personally, I cannot affirm whether the proposition "पिएरो एक शिक्षक है" is *true* or *false* since I cannot understand its meaning (in English: Peter is a teacher), since it is expressed in Hindi, which is unfamiliar to me.

An initial and fundamental classification of argumentations is that which divides them into "logical" (or "formal", including "mathematical" ones) and "factual" (including the "scientific-empirical" ones):

a) *a logical, or abstract, argumentation* asserts the "truth" (or "falsity") of the conclusion based only on the logical relations that make up a system together with the premises, after having *assumed* the "truth" (or "falsity") of the latter. Therefore, a feature of logical argumentation is *hypothesizing* – without the need for verification – the truth or falseness of the premises to deduce the truth or falseness of the conclusion based on the form of argumentation;

b) *an empirical argumentation*, on the other hand, asserts the "truth" (or "falseness") of the conclusion after having *ascertained* the truth (or falseness) of the premises. A feature of scientific argumentations is that they assert a conclusion based on premises *ascertained* to be "true" or "false", or, in any event, postulated as true pending verification or falsification.

The following argumentation is *logical*: "If we assume that Martians exist and that they are made of cheese, then if they landed in the Sahara they would melt". If the premises are true, then the conclusion would also be true. The argumentation: "Since ice melts at a temperture above zero, an ice cube in the sun in the Sahara would melt" is *empirical* or scientific and can be demonstrated to be true or false based on the factual observative reality. The *formal logic*, which has a consolidated theory and argues according to the rules of this theory, is flanked by *informal logic*, typical of the discursive arguments that are carried out in specific practical contexts (Levi, 2000; Rees, van, 2002).

I side with informal logic even if it does not have a theory because it is about arguments in actual discourse. Moreover, I'm not sure why any theory is needed to appreciate the practical value of informal logic in providing resources for critical thinking (Levi, 2000, p. 1).

Another important classification of inferences (argumentations) divides them into *deductive* and *inductive*: *Deductive* inferences have the following characteristics:

1. at least one of the premises pertains to sets (generally, open sets) of objects;

2. the conclusion is deduced from the "true" (or false) premises for one, or several, elements in the set to which the premises refer;

3. to the extent the truth of the premises can be ascertained, we can also determine the truth of the conclusion.

Inductive inferences instead have the following characteristics:

1. the premises state truths regarding a limited number of individual objects belonging to an open group;

2. the conclusions transpose the truths of the premises regarding individuals to similar truths regarding groups (open) composed of a greater number of objects;

3. even to the extent the premises (that is, the propositions concerning individual observations) are true, the truth of the conclusions can never be ascertained but is always "plausible".

The following argumentation is *deductive*: "All falling objects in a vacuum and subjected to the force of gravity have an accelerated speed of about 9.8 m/s^2; the air resistance in Pisa reduces the acceleration by "x" m/s^2; a lead ball with a radius of "y" and a mass "z" that is dropped from the tower in Pisa will reach the ground in "a" seconds at a speed of "v"". By contrast, the following argumentation is *inductive*: "I drop three lead balls with different radiuses 1,000 times from the tower in Pisa; since they reached the ground at the same time, using the calcuations of the time and space they traveled, I determine that the gravitational acceleration is around 9.8 m/s^2, independently of the weight of the objects and ignoring Archimedes' principle".

An argumentation or *line of reasoning* is logically *valid* when it is not possible for the conclusion to be false if it derives from the premises, which are declared to be *true*, by reason of the logical *connections* between the two, since the conclusion is a logical consequence of the premises. The reasoning is *sound* if it is valid and based on true premises; it is *good* if it is not only *sound* but also psychologically plausible and convincing.

A factor that makes a line of reasoning invalid is defined as *fallacious* (Fearnside and Holter, 1959). In fact, *fallacies* are "errors of reasoning" that make an argument deceptive, even if at first sight it appears sound and good. Copi et al. (2016) provide a convincing definition of a fallacy:

Logicians … commonly use the term "fallacy" more narrowly, to designate not just any error in reasoning, but typical errors—mistakes in reasoning that exhibit a pattern that can be identified and named. The great logician Gottlob Krege observed that it is one of the logician's tasks to "indicate the pitfalls laid by language in the way of the thinker." ... In this narrower sense, each fallacy is a type of incorrect argument. Of course, many different arguments may make an error of some given type: that is, it may exhibit the same kind of mistake in reasoning. Any argument that does exhibit that kind of mistake is said to commit that fallacy. The particular argument that commits some known fallacy is commonly said to be a fallacy, because it is an individual example of that typical mistake (Copi et Al., 2016, Section 4.1).

Fallacies can result from:

– *Intentionality*; at times people presenting an argument to win a debate by convincing their counterpart purposely misrepresent the facts or adopt false premises or erroneous logical connections;

– *Superficiality*; often the person presenting an argument, even though in good faith, does not possess good knowledge of logic or reasons precipitously, agitatedly or emotionally, and thereby is not able to develop sound reasoning;

– *The use of mental models*; in many circumstances the reasoning is conditioned by models of the world and by beliefs, attitudes, traditions and values that lead to reasoning based on false premises or errors of reasoning.

The process by which one tries to uncover and eliminate fallacies is "critical thinking" of the reasoning, which is particularly difficult when this is formulated using common language rather than symbolic language (Morris Engel, 2000; Walton, 2010).

[Critical thinking] … involves three things: (1) an attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences, (2) knowledge of the methods of logical inquiry and reasoning, and (3) some skill in applying those methods. Critical thinking calls for a persistent effort to examine any belief or supposed form of knowledge in the light of the evidence that supports it and the further conclusions to which it tends. It also generally requires ability to recognize problems, to find workable means for meeting those problems, to gather and marshal pertinent information, to recognize unstated assumptions and values, to comprehend and use language with accuracy, clarity, and discrimination, to interpret data, to appraise evidence and evaluate arguments, to recognize the existence (or non-existence) of logical relationships between propositions, to draw warranted conclusions and generalizations, to put to test the conclusions and generalizations at which one arrives, to reconstruct one's patterns of beliefs on the basis of wider experience, and to render accurate judgments about specific things and qualities in everyday life (Glaser, 1941, in FCT web page).

There are a large variety of fallacies (Hamblin, 1970; Tindale, 2006), and a full list would be difficult to produce (Eemeren, Van, Houtlosser, 2003). The initial classification of logical fallacies was suggested by Aristotle, who, in "De Sophisticis Elenchis" (Colli, 1955), identified

13 fallacies divided into two categories: linguistic and non-linguistic. A detailed classification can be found in Copi et al. (2016, Chapter 4). For the purposes of this study, it is useful to divide these into:

1) *fallacies of propositional truth*; these are committed when the conclusion is based on *false premises*, and they can be eliminated only by demonstrating the falseness of the premises through a search for their factual truth («All animals in the sea are fish; whales, crabs and sharks are in the sea; thus they are fish»; «The astronaut jettisoned the load in space and hurriedly returned to the Shuttle, as he heard the explosion behind him»);

2) *procedural fallacies*; these occur when the reasoning is based on procedures that do not make the correct and coherent *correlations* between the premises and the conclusion.

While the *propositional fallacies* can be identified and eliminated through empirical evidence and scientific research, it is more difficult to discover the *procedural fallacies* , since these can be of two types:

2.a) formal fallacies, which invalidate the reasoning since they do not respect the rules for *linking* the premises in a coherent schema or for properly *using* the *logical connectors* (and, or, if, then, it coincides with, etc.) and the *quantifiers* (all, at least one, etc.) used to form the argumentative statement (I told you that you should have brought cake or ice cream; you brought only cake; you were really rude!»);

2.b) informal fallacies; these occur when we attribute incorrect «*weight*» to the premises or when we wish to draw conclusions from premises that are *unnecessary and/or insufficient* for the conclusion; or more generally when, involuntarily or unconsciously, our reasoning is incorrect, and its invalidity is thus *cloaked* in an *ad hoc* argumentative form.

Informal fallacies can be further divided into:

2.b.i) *fallacies of relevance*; these occur when our reason is based on irrelevant premises with respect to the concluding proposition; that is, premises which do not allow us to ascertain the truth or falseness of the conclusions («You were distracted! For this reason you weren't lucky!»);

2.b.ii) *fallacies of ambiguity* (or *clarity*); this occurs when we reason – purposely or not – employing terms and propositions whose meaning is not *specifiable* and which are *vague* and *ambiguous*, so that it is possible to use and interpret those terms in *different ways* during the reasoning process, thus making them invalid («You wanted to be in the cooler? You won't complain now that you have six years to serve»).

Precisely because they are *informal*, the fallacies of *relevance* and *ambiguity* cannot be identified and eliminated through a standardized procedure. It is necessary *above all to understand them*; only in this way is there any hope of *recognizing* and avoiding them. *Secondly*, it is necessary to analyze the circumstances under which the reasoning takes place in order to assume the attitude of one who is «*suspicious of fallacies*» (thus, if scientific reasoning is undertaken at a researchers convention, one would not suspect informal fallacies, at least deliberate ones. However, we must adopt an entirely different attitude in examining political arguments on the eve of an election.

APPENDIX 1 provides a list of fallacies to consider when undertaking any critical analysis.

23 – Conclusions

The analyses developed in this study have laid out a basic conceptual framework (which must be developed and dealt with in further depth) for the formalization of the methodology of scientific and operational observation for constructing a coherent lexicon to guide the observer in the observation process. Obviously, the present study is neither a complete treatment nor a broad summary of the topic. I would define it instead as a "survival manual" for all observers needing to use a rigorous methodology to deal with their observations and to present them in the form of an appropriate language.

In fact, we have considered the elementary observative activities: the perception and identification of "objects" (dimensional vector), the determination and description of "objects" (technical description), and analogical generalization (technical definition). We then introduced the problem of knowledge regarding the universe of objects of observation. To thoroughly deal with this problem, however, it is necessary to consider other observational activities, which we shall term "non-elementary", through which the observer jointly considers a variety of objects of observation that form groups and structures (sets and systems), which he views, in turn, as objects of observation that can be represented in "models".

It was then considered indispensable to abandon the hypothesis of an isolated observer who observes without communicating. Science advances thanks to the exchange of information about observations by scientists and research groups. For this reason, an initial examination of the notion of *sign*, *language*, *meaning* and *linguistic definition* was undertaken by specifying the uses of language and the characteristics of the scientific languages needed to present argumentations.

Finally, the paper has dealt with the broad topic of the instruments needed to analyze scientific argumentations and explanations, since scientific and operational observation seeks an understanding and explanation of reality, proceeding through inductions and deductions and through logical and factual argumentations.

Note that the treatment of the topic employed terms that were simplified as much as possible. A limited use was made of symbols, turning to these only when there was the absolute necessity of a formal definition. Even the treatment of the theory of sets and systems was limited to presenting only the qualitative aspects. Simple examples were used when possible, taken from daily observation. Nevertheless, the topics dealt with are capable of being developed in more detail. Only a few topics were developed in detail to offer the reader immediate operational tools.

This study presents many limits in terms of content, the most important of which concern the *problem of judgment*. In fact, judgment represents the moment in the cognition process that cannot be eliminated. Judging means associating a quality to an object, behavior or event that favors its recognition for the survival of the cognitive system. To survive in a competitive environment, a cognitive system (observer) must provide rapid and sensible judgments not only regarding facts and circumstances but especially actions, behavior and other subjects with whom we interact. There are three forms of judgment:

1) *observative* or *convincing* judgments, which we express when we *recognize* an object, event or phenomenon, identifying its *model* – whether this entails description or definition – or the *name* denoting it; it thus appears as the statement of a *conviction*, needed to gain new knowledge, expressed as a true/false binomial (I believe/don't believe, I hold/don't hold, etc.);

2) judgment of *truth*, or *verification*, when we determine the truth of a declarative proposition; this can be a judgment of empirical truth or logical truth and involves reasoning and explanations;

3) *evaluative judgments*, or *appreciation*, aimed at *objects* and involving the sensory experiences of the subject (sensory judgment), or at the *behavior* of other subjects (operative judgment); such judgments are translated into the general binomial: attraction-repulsion (good-bad, positive-negative, beautiful-ugly, favorable-unfavorable, appropriate-inappropriate, I like it-I don't like it, even in all the varieties of jargon). This limit represents a stimulus for a more detailed treatment in a future work.

APPENDIX 1 – Formal and informal fallacies

Since *critical thinking* assumes knowledge of the fallacies, some brief discussion of the main fallacies is appropriate based on the formal list provided by Copi et al. (2016, Chapter 4), starting with the more common *procedural fallacies*.

There are many kinds of *formal fallacies*, the most common of which can be summarized as follows:

a. *A deceptive enthymeme*; an argument is enthymematic if several premises are concealed which are normally accepted in a given argumentative context, and thus are implicit. The fallacy originates when the conclusion deceptively derives from premises that are different from those that normally would have to be implied, thus leading to an unexpected conclusion («Do you want me to describe a paranormal fact? I squeezed a rock between my fingers; when I opened them, the rock, pushed by a mysterious force, shot toward the ceiling»; the premise which is normally implied: «you were in a gravitational field»; the deceptive, non-explicit premise: «I was in a space characterized by uniformly accelerated fall»).

b. *Contradiction*; a contradiction originates when the same conclusion can be made to derive from different and contrasting premises. The fallacy appears when one of the contradictory premises is purposely ignored in the inference («I don't like either cold desserts or sweet ones; therefore, I'll order whipped cream»).

c. *Tautology*; a tautology is reasoning whose conclusion coincides with the premise or with one of the premises. The fallacy originates when the tautology is ignored and the conclusion is held to be valid. If, instead, the conclusion appears in the premises, we are guilty of the *petitio principii* (Begging the Question), a typical non-formal fallacy («Why is Piero always sleeping? Because he's a sleepyhead»).

d. *Either/Or;* this fallacy occurs when the conclusion derives from premises linked to the connector Either (one or the other, but not both), interpreting it as Or (one or the other, or even both), or vice-versa («Are you crazy! You came to the party with Maria and Carla?»; «Of course! Didn't you tell me to invite Maria or Carla?»).

e. *Triple negation*; using a chain of negation that is too long may make it difficult to interpret the premises and lead to a fallacious conclusion («Whoever does not say to not lie, lies»).

f. *False modus tollens*; this is a very common fallacy based on the belief in the reversibility of the implications. Given the implication «A→B», it is valid to infer «if A, then B» (modus ponens); or «if not-B, then not-A» (modus tollens). However, obviously if A implies B, B does not necessarily imply A. Deriving the conclusion from a false *modus tollens* represents an irreversible fallacy («I you have a cold, you nose runs. Since your nose is running, tell me how you caught a cold?»).

We shall now examine *fallacies of relevance* using the terminology by which they are normally referred to.

1. *Argumentum ad hominem n. 1* (against), or 'poisoning the well' fallacy resulting from the *disesteem* of someone. In this case, instead of demonstrating the truth of a conclusion, the

reasoning capacity of the person making an argument is placed in doubt, independently of the supporting premises («John can believe what he wants; however, he is a member of that party – or: he comes from such and such a country, he was convicted of..., they say that he..., he was seen in..., etc. – so what he says can't be right (or true, correct)»; the fallacy derives from the fact the truth of the reasoning is not linked to the personality of the individual presenting it but to the premises set forth).

2. *Argumentum ad hominem n. 2* (in favor), or *argumentum ad verecundiam*, or the "Star Power" fallacy. This is similar to the preceding fallacy, except that the truth of the thesis is supported not on the basis of the premises but of the sole fact it is accepted, or recognized, even by someone who is esteemed, trusted and accorded reverence («All the nerves start from the heart; this must be true, since this was even affirmed by Aristotle»).

3. *Argumentum ad hominem n. 3* (circumstantial), or fallacy of an *argument due to the particular circumstances* an individual finds himself in. This entails seeking the truth or supporting the falsity of a conclusion appealing to the particular circumstances of the person asserting it or of the person who must accept it («We committed tax evasion because everybody does it!»).

4. *Argumentum ad baculum*, or fallacy of the *appeal to force*. This occurs when there is an appeal to the use of force, or the threat of it, to make one's conclusions accepted, even though these are not based on sufficient premises («Profits are falling, so we must work more; otherwise, I'll be forced to make mass firings»; the fallacy derives from the fact that the premise, «profits are falling», is not sufficient to justify the conclusion).

5. *Argumentum ad misericordiam*, or the *appeal to pity* fallacy. This is when one attempts to have one's conclusion accepted by playing on the "pity" of the counterpart (this is often used by defense attorneys: «How can you find this woman guilty and condemn her small children to be left on their own?»).

6. *Argumentum ad ignorantiam*, or the argument from Ignorance based on the *lack of evidence to the contrary*. This fallacy is very important. On the one hand, it is difficult to identify, and on the other very common and tolerated. It is committed when: (a) it is inferred that a conclusion *must* be true because it has *not* been proven to be false (in this form, the fallacy is even given legal status in many constitutional systems that state that the accused is innocent until proven guilty); (b) it is inferred that a conclusion is false because its truth has *not* been proven («metaphysical phenomena do not exist because if they did they could be proven just like physical phenomena can be»). It must be noted that in some cases this fallacy is only *apparent*. At times we can assume that, if an event had occurred, it would be possible to demonstrate it («If you had written me, the letter would have arrived»); for this reason, without proof of the event, we can conclude the event has not been verified («The letter didn't arrive; therefore, you didn't write to me»). In truth, this proof is not based on ignorance of the event; otherwise, one would commit *false modus tollens*. On the contrary, it is based on knowledge of a causal or functional relation; if the event had occurred, its effects would have been certain («If you had written me and posted the letter in the letter box for London, then it would have been delivered in England»). It must be further noted that this fallacy is not committed if: (i) one ascertains the truth of the conclusion by demonstrating that it is *not* false («The accused is innocent because at the time the crime was committed he was elsewhere»). This is the rule also used in arguments «based on incredulity»; (ii) the falsity of the conclusion is ascertained because it is demonstrated that *it is not* true.

7. *Argumentum ad populum n. 1*, or fallacy based on *recourse to passion*. This occurs whenever one tries to gain agreement regarding a certain conclusion by members of a group by arousing the «popular passion» or «enthusiasm» of the crowd. In addition to orators, advertisers also

use this type of fallacy («Beta milk is better because it's the official milk of the Dutch national football team!»).

8. *Argumentum ad populum n. 2*, or the *appeal to the masses*. In this case, the conclusion is declared to be true because it is *believed* to be true by a large number of people («Product X is better because its the top-selling product»).

9. *Red herring* and *straw man*. These fallacies entail "turning attention away" from the main argument by including among the premises some attention-grabbing factor that is not relevant in ascertaining the truth or some element that exaggerates the effects («This economic policy aimed at growth is wrong because we must vigorously oppose economic inequality, which this policy permits»; «These forms of widespread control using videocameras are unacceptable because they transform the state into «Big Brother»).

10. *Accident n. 1*, or fallacy of the *generalization from the particular*. This fallacy is committed when a general rule is applied even to a special case, which, occurring under peculiar or abnormal circumstances, cannot and must not be included in the rule («Any error in the balance statement entails a falsity; in this financial statement, the cash balance has been rounded off by 5 cents, and therefore the statement is false»).

11. *Accident n. 2*, or fallacy of the *hasty generalization*. This occurs when hasty generalizations are made starting from special and exceptional cases that do not lend themselves to being included in a valid rule that takes in other cases as well, or from samples that are unrepresentative («It has been ascertained that the three oil companies that underwent a tax audit had a percentage of tax evasion not lower than X% of their taxable income. Ergo, the tax evasion of all companies dealing in oil products is not lower than X%»).

12. *Non sequitur n. 1*: «non causa pro-causa», or the *questionable cause* fallacy. This is when a phenomenon is considered to be a *cause* which does not possess that attribute («The fall in profits was due to a fall in sales». This proposition is based on the decline in sales, even if the fall in profits can be attributed to an excessive increase in prices leading to a decrease in demand).

13. *Non sequitur n. 2*: «post hoc, ergo propter hoc», or fallacy of *antecedence*. This occurs when an event is inferred to be the cause of another simply because the first event precedes the second («You arrived and brought good weather with you»; «We had the accident because a black cat crossed the street in front of us»).

14. *Petitio principii*, or the *Circular Argument* fallacy. This is committed whenever the conclusion of an argument is taken as the premise. The fallacy is revealed when what is identified in the conclusion is not explicitly set forth in the premises, such as in tautological arguments («It's raining hard because a lot of water is pouring down from the sky»; «The strongest animals are those that survive because we know that the strongest always survive»).

15. *Plurium interrogationum*, or the *Complex Question* fallacy. This fallacy has several variants, the most common of which being when one expects a single response to several questions posed simultaneously when the situation instead require separate answers; this fallacy is widespread whenever uniform approval is sought regarding a document containing different clauses. The fallacy occurs even when an answer is sought to a question that incorporates another, non-explicit question («How long does a bar of soap last?»; by answering this, one also answers, though indirectly, the question «How often do you wash?»).

16. *Ignoratio elenchi*. This is when an argument aimed at demonstrating a specific conclusion is used instead to demonstrate a different one, whereby one attempts to get the first conclusion accepted («Do you want to beg for bread?»; a negative answer could be used to reach the conclusion «Work more and spend less»).

17. *Counterfactual reasoning* or f*alse temporal alternative.* In this case one assumes a consequence derives from acts that have not taken place in the past but have only been assumed. In fact, it is not possible to simulate today the effects of past behavior («If instead of taking that road you had taken the other, you would have arrived earlier» is acceptable reasoning if based on knowledge of the traffic conditions along both roads. However, the following reasoning would be unacceptable: «Even if you would have left later, you would still have had the accident. When destiny calls…», since an accident requires the combination of a system of temporally-related events that cannot be reproduced, except by chance at a different time. Equally fallacious is the argument: «If General X had not led campaign Y (2,000 years ago), our people would not be in these conditions today»).

Let us now examine the more common *fallacies of ambiguity*.

a) *Equivocation*. In this case, during a process of argumentation a term having several meanings is used with different meanings («I wanted to acquire something; being in the sun, I acquired a beautiful suntan»).

b) *Amphiboly*. This fallacy is committed when the premises are formulated ambiguously or incorrectly regarding their grammatical construction, so as to lead to different interpretations based on the meaning given to them. The conclusion will be true or false according to how the premises are interpreted («You will see, Tomorrow!»; if this were the response of an orator, it would have a clear threefold meaning).

c) *Accent* or *extrapolation*. We have all experienced how a different emphasis given to a term can modify the meaning of an entire statement; this fallacy is widespread since it is committed, for example, whenever one cites another's statement using an excerpt that, taken in isolation, would have a different meaning from that which the author wanted to provide when taken in context; or when one adapts the title of a book or article to offer a guide to its interpretation).

d) *Composition*. This occurs whenever there is equivocation regarding a whole and a group, attributing properties to the individual components of both that characterize the whole or group itself («People are numerous; therefore, every person is numerous»; or «The apostles are twelve in number; since Peter is an apostle, he is twelve in number». In the first case, the property of a whole is attributed to an individual, while in the second the power of a group is associated with an individual).

e) *Division*. This is the opposite fallacy to that of composition; it occurs when we infer that what is true of a whole can be true of, or assigned to, its components; this fallacy appears when we attribute quantities of whole and non-divisible objects to the objects that derive from their assumed separation; «If a table can support 16 kg, then each of the four legs can support 4 kg»).

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[As this study deals with the topic of knowledge from multiple points of view, a complete bibliography may appear to be boundless. Here I have only listed the works cited in the paper. Generally, I will give priority to the authors that first presented and developed such topics, rather than citing authors that dealt with them more recently.]

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