

Facing the tragedy of change in the semiotic process: the role of science

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Abstract

We offer an interpretation of the concept of integrity and quality of science, based on semiotics. We argue that science can be seen the part of a semiotic process, in charge of making useful representations of relevant events. In turn the semiotic process then tests the usefulness these representations in an impredicative way. The preservation of the semiotic process requires a continuous update the set of identities assigned to the functional and structural components making up the society, which can only be obtained by adopting pertinent representations. In this process, the quality of information is defined as “fitness for purpose”, not as an universal value. The fitness of scientific information depends on the definitions of what is useful, what is relevant and for whom, which are all dependent on a previous definition of the “we” (the self of the semiotic process). The integrity of a semiotic process can be defined as the capacity to produce and use a pool of meanings associated with recorded information required to guide action and to preserve in this way the identity of an autopoietic system (a system producing itself). The complex organization of the semiotic process in human societies implies that the preservation of the identity of the whole is the result of a continuous negotiation and deliberation over the identities of the lower level constituent components. In reflexive systems there are several distinct definitions of identity that have to be negotiated across levels of organization (individuals, households, communities, countries, etc.). The feeling of living in a post-truth world signals a failure in the task of preserving the integrity of the semiotic process. The production and use of information in the step “represent”, required for guiding action across different levels of organization, has lost coherence across the different obsolete definition of identities and the process is not capable of generating an integrated set of new ones at the required pace. Crises of science are coupled with social and political crises in an impredicative way: the representation provided by science is no longer useful for society and the validation provided by society to the information used to guide action is no longer useful for science. This requires a move from a substantive use of science as a source of facts about the world, to a more reflexive use of science as a source of useful information about concerns: how to deal with the tragedy of change.

Key words: Semiotic process, Integrity and quality in science, Post-Normal Science, Post-truth world, Tragedy of change, Science for Governance.

1. Introduction

In this paper, we offer an out-of-the-box interpretation of integrity and quality in science, based on semiotics, complexity theory, and thermodynamics. Societies are defined as complex adaptive, becoming and anticipatory systems. The process of decision making in societies is described as a semiotic process, in which signs (observations about the external world) are used to make sense of the external world and guide action. Within this framing, we suggest that science can be seen as a set of institutionalized activities taking place inside the semiotic process carried out by societies. This interpretation is compatible with the key elements used to define science in dictionaries: a system for acquiring knowledge, a systematic generation of knowledge through observation and experimentation, watching, measuring and doing experiments to describe and explain natural phenomena.

In our semiotic narrative science is the functional component of society specialized in interpreting signs coming from the external world to build useful perceptions that are used to generate representations of events. Scientific representations provide explanations of causality over observed interactions by adopting specific disciplinary lenses. Explanations are used to develop anticipatory models, that is, to provide advice on action that should be taken based on expected future states. An example of anticipatory model provided by science in the semiotic process is the call for mitigation and adaptation actions based on the expected future state of climatic change.

It should be noted that in the past the role of knowledge producer in society was not a monopoly of science. A variety of forms of knowledge associated with religious beliefs, superstitions, traditional wisdom built on recorded and shared experiences, and cultural norms were all legitimate factors used in the process of decision making. With the emergence of modern science, these alternative forms of knowledge required to preserve the plurality of meanings associated with existing representations have been progressively marginalized – not in praxis, but at least in the official story-telling. The scientific revolution has contributed to generate a general consensus that scientific knowledge – a typology of representations based on a given taxonomy of signs valid by default for a given taxonomy of interpretants – could substitute the various forms of traditional knowledge through a unifying grand narrative, as exemplified by the Encyclopedia of Diderot and d'Alembert.

We share some of Lyotard's (1979) scepticism towards grand narratives and argue that in post-modern societies quality and integrity are necessarily context-specific concepts. In semiotics, the meaning of the signs is determined by the perception of the interpretants. Therefore the ability of preserving meaning depends on the coupling between the typology of signs (assumed to carry a given meaning) and the typology of interpretants (the intended users of the signs). Quality and integrity cannot be assessed without addressing the special relation between the sign (why that sign? A sign produced when and by whom?) and the interpretant (who are the interpretants? When and where do they interpret the sign?).

The problem of matching signs and interpretant becomes overwhelming in a situation in which the semiotic process is subject to a dramatic acceleration, such as during revolutions. The definition of the identity of both the observer (the self as determined by the semiotic process) and the observed (the other as determined by the representation of the external world) change at a speed that cannot be handled by the existing institutional settings. In relation to this point,

in order to propose a heterodox explanation of the challenges of quality and integrity that modern science is experiencing in the post-truth days, we start from scratch, framing the discussion of the role of science in the semiotic process. This requires introducing a few concepts useful to understand and describe the role of knowledge in the functioning of self-organising, adaptive, and reflexive systems. We then provide in section 3 a description of the role of science in the process of decision making of modern societies. After having illustrated the theoretical concepts on which the paper is based, we provide an alternative to contextualization of the use of the terms *integrity* and *quality* in relation to scientific activity in section 4. Section 5 concludes the paper with a forward outlook.

2. Theoretical concepts from the field of complexity used to explain the functioning of complex adaptive systems

This section uses concepts from complexity theory, thermodynamics, and semiotics to discuss the role of information in self-organizing systems, and then draws a parallel with the role of scientific knowledge in society. We draw from a broad literature to take the following steps: first, we introduce the concept of dissipative systems and discuss the question of identity in far-from-equilibrium becoming systems. Second, we argue that becoming systems are anticipatory systems rather than reactive systems. Anticipation requires purposes and beliefs. We show that purpose may be realized in structural and functional system components, but there is no one-to-one mapping between function and structure. Third, we introduce the concept of holon to handle the duality between function and structure. Constituent components at once define their identity and the identity of the whole through multiple mappings between functional and structural components. Fourth, we use Peirce's semiotic process to describe how science is used by complex adaptive social systems. Finally, we explain the semiotic process of societies as a challenge of a plurality of reflexive and self-aware holon-like individuals that define their own identity and that of society, and reflexively engage with the multiple identities they constitute and are constituted by.

Step 1: Self-organizing systems become something else in time

An important contribution to the study of complex systems comes from non-equilibrium thermodynamics. For our discussion we focus on the concept of dissipative systems (Glansdorff and Prigogine 1971; Nicolis and Prigogine 1977). Dissipative systems face a systemic existential predicament. Dissipative systems are open systems, which means that they must be able to preserve an *identity* that makes them different from their context but at the same time they are *made-up* of their context because of their openness. Schrödinger (1967) in his seminal book "What is life?" explains this predicament by proposing the concept of negative entropy (a blasphemy in classic thermodynamics). The expression of a metabolic pattern requires a continuous consumption of useful inputs (taken from the context) and the continuous production of useless wastes (dumped into the context). The metabolic process that expresses the identity of a dissipative system must be capable of stabilizing in time an integrated set of structural and functional elements required to reproduce the system over time. This stabilization entails a dialectic relation with the environment: the very activities that sustain the

existence of metabolic systems (e.g. consumption of natural resources) destroy the admissible environment on which they depend. To make things more difficult, the openness of dissipative systems implies that it is not simple to define what these systems are. No matter the complexity of the dissipative structure – from a simple tornado to a complex megacity – dissipative systems are always composed of two types of constituent component:

- (i) The dissipative structure – the set of structural and functional elements that produce positive entropy (+dSi); and
- (ii) The support system – the set of processes taking place in the context required to restore the favorable gradients destroyed by the dissipative structure. These processes must generate an adequate flux of negative entropy (-dSe).

This forced mutual relation between the two constituent components of dissipative systems is visualized by the famous equation proposed by Prigogine: $dS_{DS} = +dSi - dSe$. This equation clearly frames the predicament of dissipative structures – including modern societies. Their survival (the possibility of increasing +dSi according to processes controlled by humans) depends on a set of processes that generate the required flux of negative entropy (-dSe) on which the dissipative structure does not have any control and cannot fully predict. This condition implies the systemic presence of uncertainty about the stability of existing favorable boundary conditions. Uncertainty about the stability of favorable boundary conditions can be seen in the panic generated in ancient history by eclipses and the possibility of climate change nowadays. This predicament is more pronounced in modern societies, whose metabolic systems grow both in (i) size and (ii) pace of activity per unit of size. The more the economy grows, the more the stability of uncontrollable processes that determine -dSe becomes important.

In summary, whereas simple dissipative systems, such as a tornado or a whirlpool, have a local identity fully determined and dependent on ephemeral boundary conditions, modern economies managed to operate over large time intervals (centuries) and large spatial domains (they cover nowadays the entire planet) while maintaining their identity. To obtain this result, modern economies have learned how to control and adapt to unavoidable changes in boundary conditions. Since thermodynamic laws force human societies to be “becoming systems” (Prigogine 1978), they must be able to be effective “anticipatory systems” (Rosen 1985). Anticipatory systems purposefully change their behavior to maintain their identity, as opposed to reactive systems that change as a consequence of changes in the context.

Step 2: Learning requires purposes and beliefs

Anticipation can be defined as using expectations about the future to guide present action (Poli 2017). This definition is based on the concept of “anticipatory systems” (Rosen 1985), which are defined as: “an anticipatory system is one in which present change of state depends upon future circumstances, rather than merely on the present or the past. As such, anticipation has routinely been excluded from any kind of systematic study, on the grounds that it violates the causal foundation on which all of theoretical science must rest” (Rosen 1985: v). Anticipation requires self-referentiality, the ability of both reproducing oneself (process of fabrication) and of making models (to be used in the system of control) of oneself interacting with the external world.

Several concepts have been proposed to explain the self-referentiality of living systems: (i) Rosen (1985; 1991) called this class of system Metabolic-Repair systems (M-R systems) and defined them as “closed to efficient cause”. M-R systems are able to reproduce and repair themselves through their metabolic activity and they contain models of themselves that enable them to be their own makers; (ii) H.T. Odum (1971; 1983) in theoretical ecology provided a similar description of processes that enable ecosystems to reproduce themselves, which he called “informed autocatalytic loops”; (iii) Margalef described the organization of an ecosystem as “a channel which projects information [to itself] into the future” (Margalef 1968: 17); (iv) Maturana and Varela (1980) proposed the concept of autopoietic systems. “Autopoiesis literally means self-production or self-creation, and is a term for the “self-defining”, “circular” organization (organizationally closed but structurally, i.e., materially and energetically, open) of a living system (such as a cell), consisting of a network of component metabolites that produces the very network and its own components plus the boundary of this network” (Emmeche 1997).

All these conceptualization have three points in common: (i) the key role played by information in the process of self-organization; (ii) a distinction between *the self* and *the other* in the analysis of the interactions; and (iii) the presence of *the self* in the anticipatory models of interaction.

Adaptation based on recorded information requires learning and learning requires the creation of notional systems. A human activity system can be defined as a “notional system” (i.e. not existing in any tangible form) (Patching 1990), if the activities undertaken achieve some purpose. In relation to this point, Pattee proposed the concept of *semantic closure*: “Metaphorically, life is matter with meaning. Less metaphorically, organisms are material structures with memory by virtue of which they construct, control and adapt to their environment. Evolution entails semantic information, and open-ended evolution requires an epistemic cut between the genotype and phenotype, i.e., between description and construction” (Pattee 1995: 24). According to Pattee (1995), semantic closure is the process that makes it possible for life to add *meaning* to *matter*. Meaning can only be obtained by creating notional information in the description of the functioning of systems and testing the usefulness of this information by using it to: (i) construct structural elements; and (ii) control the activity of functional elements. This iterative commuting between producing information (in notional terms) and testing information (in the external world) has been suggested also by other authors. For example, Simon (1962) argues that life is a process of resonance between making recipes used for making processes used for making recipes, and Prigogine and Stengers (1984) assert that life is a process that uses DNA to express a metabolism capable of reproducing the DNA. The rationale of this process of storing memory of past experience is at the basis of the discipline of *biosemiotics* - an interdisciplinary approach that studies the modalities and the role of signification in living systems. Von Uexküll (1957) developed the theory considering animals as interpreters of their environment (for a detailed history of the field see (Kull 1999).

It is important to observe that recording information is not enough in order to be able to learn. There is something more that living systems must have in order to be able to learn (Pattee 1995). A learning system must have:

1. A *purpose* associated with its own identity. The definition of a purpose makes it possible to compare the *expected result* with the *achieved result* – i.e. the feed-back from the

external world that can be used to check the validity of the information. Purpose makes it possible to distinguish a success from a failure and to learn;

2. A *belief* associated with recorded knowledge determining the operation of a system of control. The belief indicates what should be done to achieve a specific goal in a given situation. In adaptive systems, beliefs are updated through feedback;
3. A *system of control with contingency*. Contingency is essential because it determines the difference between physical laws and semiotic controls. For example, the behavior of a flame is determined by the characteristics of an attractor regulated by physical laws. A flame cannot learn how to behave in a different way: it is a simple dissipative system fully determined by its boundary conditions. On the contrary, the behavior of an organism (e.g. a cat) is determined by both the characteristics of its structural organization and by its semiotic controls. Both of the structural organization and the system of control can be adjusted. Controls reflect the information accumulated (memory) by the species-ecosystem complex, to which the organism belongs, in past interactions with the external world;
4. *Validation through action*. Semiotic closure can only be obtained by testing beliefs in relation to the purpose in the chosen semiotic control. Depending on the results, the system can adjust the structural organization, the semiotic control, the belief or, as a last resort, the purpose. This validation requires generating instances (material observables in physical system) of the types described by the recorded information (immaterial observables in notional systems).

As explained in Giampietro (2018) "Note that changes in semiotic controls can refer to two different things: (i) the definition of the structural organization of the system and its parts; and (ii) the effectiveness of anticipatory models. For example, a simple anticipatory model used by a cockroach could be "light equals danger" (the belief) coupled to the normative narrative (system of control) "if there is light, then run for darkness". This type of information, coupling a "belief" to a "system of control", may be applied to different structural types (e.g. cockroaches, silver fishes, and earwigs)". In the alternative, change could occur through the development of more sophisticated structural elements (e.g. a dog) that can express a more effective set of semiotic controls.

The analysis given by Pattee (1995) is based on a combination of biosemiotics and cybernetics used to explain how complex self-producing system can learn. In self-reproducing metabolic systems the mechanism of entropy generation is determined by semiotic controls, which define constraints that reflect the effect of *adjustable rules* and not of *inexorable laws*. The difference between rules and laws is essential because it represents one of the prerequisites of learning from anticipation. This distinction implies that the identity and the functioning of complex adaptive systems can only be studied by considering a few *immaterial observables* – i.e. purposes, beliefs, semiotic controls – which play a key role in the definition of the behaviour of self-referential systems. On a basic level, all living systems have the purpose of remaining alive and reproducing themselves. They do so by generating and using information about themselves (beliefs). Reflexive systems such as human systems can add additional purposes to their identity.

Step 3: The epistemological conundrum of the holon

Self-organizing adaptive systems effectively use recorded information by generating and preserving the meaning of codes, as studied by codepoiesis (Barbieri 2012; 2015). Recorded information can be used to make structures, i.e. DNA or blueprints used to generate equivalence classes of structural elements, and to make system of control that store experience.

In a metabolic network, made of self-reproducing elements, information is generated and reproduced in two non-equivalent ways:

- (i) Directly, through blueprints used to produce the structural elements that operate the network nodes (e.g., DNA or blueprint for human artefacts). Blueprints can be thought of as information stored in the system of control. The blueprint is the genetic information that produces equivalence classes of organisms (populations belonging to the same species, e.g., rabbits, deer, horses), determining *upward causation*; and
- (ii) Indirectly, by building mutual information inside complex adaptive systems, determined by the forced impredicative relations between the different characteristics of the constituent components. That is, a metabolic network defines a *network niche* for the functional nodes – what the network expects the specific constituent components to do. The characteristics of a structural element of the network niche must be compatible with the expected characteristics of the functional element defined by the mutual information of the network. This mutual information determines *downward causation*. For example, mutual information is associated with the amount of biomass that herbivores obtain from plants and the biomass they transfer to carnivores. The congruence requirement defines how many elements of the various equivalence classes – populations of plants, populations of herbivorous, and populations of carnivorous – can be reproduced in a given ecosystem.

In the formation of ecological holarchies, there are several identities that define each other in an impredicative way – by integrating *upward* and *downward* causation through an impredicative set of relations – cells, tissues, organs, organisms, populations, ecological niches associated with species, ecosystems, biomes, Gaia.

In complex adaptive systems, the issue of control is even more challenging. The definition of “the self” used in the system of control has to be different at different levels of organization; and the various definitions of “the self” evolve in time. When considering complex adaptive systems as a whole, learning refers to integrating changes in the identities of structural and functional components across scales, while reflecting changes in the definition of purposes determined by the feed-backs received in past actions.

Complex adaptive systems face a serious epistemological problem in defining the relation between the representations of functional and structural elements. The notional definition of functional components – i.e. what the element does – does not map in a deterministic way onto the notional definition of structural components – i.e. what the element is. For instance, the notional definition of the functional component “herbivores” of an ecosystem can represent herbivores as processors that establish a relation between the amount of biomass taken from

plants and that transferred to carnivores. On the other hand, the notional definition of structural components will refer to any of the various species of organisms – e.g. rabbits, cows, snails – that display the physiological characteristics of herbivores. The effectiveness of a given functional-structural coupling and the use of notional definitions of functional and structural components can only be validated through a semiotic process by referring to a tangible metabolic process in which the functional definitions of processes that take place in ecosystems and the structural definition of processes that take place inside individual organisms are congruent with each other. An ecosystem is healthy only when the aggregate characteristics of the mix of structural elements (categorized as “herbivores” in functional terms in the notional system) removes the expected amount of plant biomass from the lower level and provides the required amount of herbivore biomass to the upper level of carnivores. The metabolic pattern of an ecosystem is used to check if the mix of structural elements expresses the expected function. If the ecosystem is healthy, then the structural characteristics of the populations of herbivorous species match the expected characteristics of the functional node herbivores.

The concept of “holon” has been proposed by Koestler (1967; 1969; 1978) to deal with the systemic degeneracy of the mapping between structural and functional types in complex adaptive systems. In his book “The Ghost in the Machine”, Koestler (1967) shows that there is always an immaterial component of an organized system (the ghost is the notional part) associated to the meanings of the parts contributing to the expression of an emergent property at a different level of analysis.

Step 4: The semiotic process in human society

The epistemological problem associated with the concept of holon (a degenerate mapping between functional and structural type) is deep because one cannot observe structural or functional types as such (Giampietro, Allen, and Mayumi 2006). One can only observe *instances* (specific material realizations) of either functional or structural types. Different structural types (e.g., rabbits, cows, sheep) can map onto the same functional type (e.g., herbivores) and the same structural type (e.g., rabbit) can map onto different functional types (e.g., father, herbivore, meat for dinner). The distinction between *instances* and *types* is essential to learn and evolve. Instances can learn, types cannot. However, instances cannot evolve (they either live or die). The functional and structural types associated with an instance undergo evolution, and they are associated with notional representations – recorded information evolving in time. Holons can only learn and evolve, when operating inside special realizations of holarchies. A holarchy is a cascade of constituent components that play the role of both structural and functional elements across hierarchical levels. What makes learning and evolution possible is the ability to generate and update the meaning of notional representations.

We refer to the semiotic process to explain how information is generated and updated by the holon. Semiotics is the study of how signs are used by a system to stabilize its identity. According to Peirce (1935), the semiotic process is composed of three iterative steps: (i) the production of signs (represent); (ii) the interpretation of signs (transduce); and (iii) the application of the sign to guide action (apply). This iterative process can be represented as:

→ apply → transduce → represent → transduce → apply →

Purposes and beliefs have to be preserved because they are used in the semiotic process in the step “transduce”. In living organisms, transducing refers to the process of converting physical energy into nervous signals and use nervous signals to control physical energy.

In societies, the semiotic process can be interpreted as the interaction between three elements, associated with the three steps described above. In modern societies, science is in charge of providing the inputs for the step “represent” of the semiotic process. Scientific information is then transduced into policy options and recommendations for action which are fed into the governance process. Scientific information may be used to negotiate power relations between social actors and institutions, update and prioritize competing narratives, restructure the organization of social constituent components, and update semiotic controls.

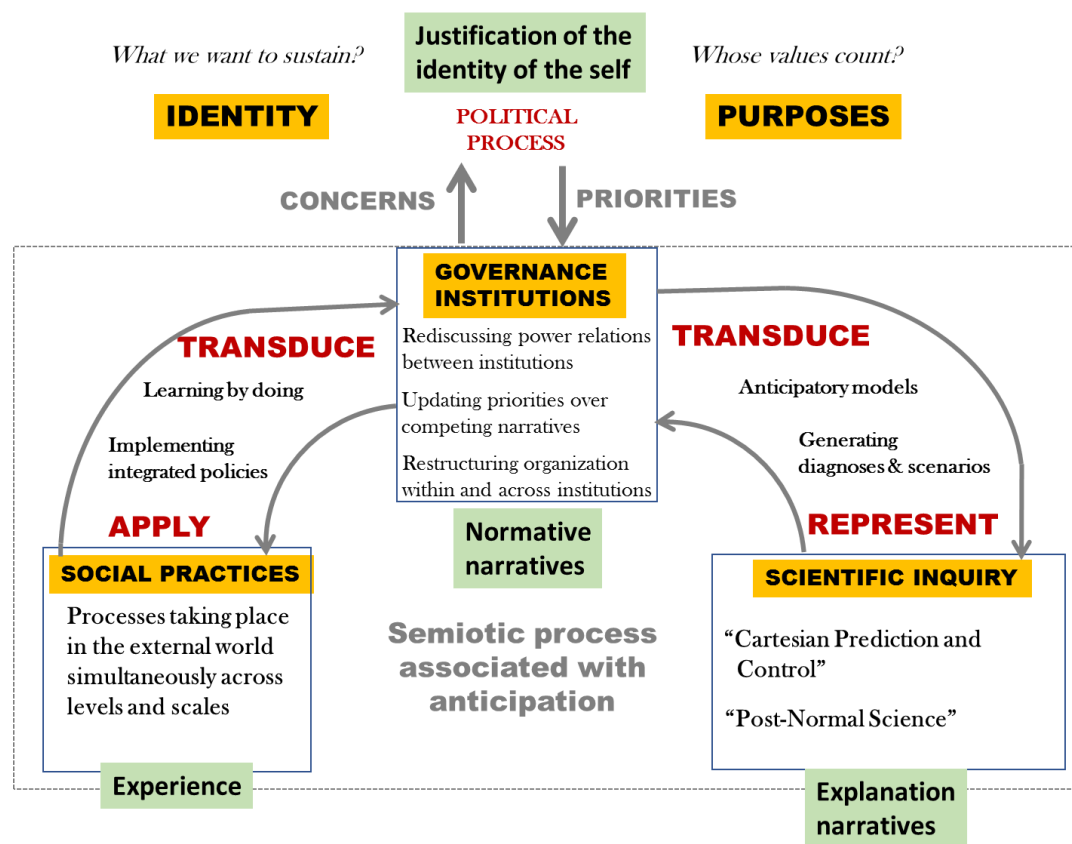


Fig. 1 The semiotic process in society (adapted from Giampietro, 2018)

As a result of scientific and other inputs, information is transduced in the formulation and implementation of policies, which are “applied” in the third step of the semiotic process. In figure 1, we refer to applications to the external world for simplicity. Policies may also be reflexively applied to the governance process itself (e.g. by introducing or updating rules and systems of control, by changing narratives). Iterations in the process are enacted by the reverse flow of information – what the society learns from the results of its actions. Applications also generate information about the validity of the semiotic process as a whole (learning by doing), which is transduced and fed into the governance process, and then used as information to define priorities and funding research and development activities (affecting the step represent).

In social systems, transduce requires handling (produce, preserve, use and update) meaning. However, the handling of meaning required to guide action – if the light is red, then stop the car – requires the existence of *an interpretant*. The definition of the interpretant in living systems is not simple. For example, who is the interpretant of the information about the survival of the fittest used by living systems? In natural selection individual organisms either die or survive, so they cannot learn how to improve their system of semiotic controls. Biological populations to which a specific organism belongs do not do the learning either. So we have to go up in the organization of the holarchy to find the right level at which the emergent property of meaning emerges. In figure 1, the questions about the interpretant are addressed in the upper quadrant when deciding about identity and purposes.

Step 5: Who is us? The contingent identity of the constituent components

Relational analysis (Rosen 1991) studies the function of components in complex adaptive systems. In particular, it addresses the mechanism through which the whole can express a different meaning from the meaning associated with its parts, when considered in isolation. According to relational analysis, self-reproducing adaptive systems are made of constituent components that are its functional parts. They cannot be eliminated without affecting the stability of the whole. The relation between the structural and functional elements of constituent components can be described using Aristotle's four causes. A constituent component must have: (i) a final cause – it must express a function that stabilizes both the identity of the whole and its own identity; (ii) a formal cause – it must have a structure recorded in its notional representation (e.g. the blueprint); (iii) an efficient cause – it must be able to express agency (reproduce itself by expressing an expected behavior in the case of living systems); (iv) a material cause – it must be a physical realization of the notional representations of its structural and functional elements.

This definition implies a bifurcation in the possible representations of the system:

- (i) Representation by downward causation: the system's identity is defined from the external view, by observing how the system as a whole interacts with its context. According to the external view, the identity of the whole defines the identity of the parts. In this representation, there are two issues to be considered when assessing the identity of a system: (i) the external constraints (how robust the system is in relation to the limits associated with the availability of $-dSe$) and (ii) the internal constraints (how robust the system is in relation to the limits associated with the production of $+dSi$); and
- (ii) Representation by upward causation: the identity of the system is defined from the internal view, by observing how the activity of the various parts stabilizes the whole. According to the internal view, social systems can change both structural types (the formal cause – the information in the blueprints used to make structural types) and semiotic controls (the efficient cause – the processes used to express functions). However, parts inside the whole do not have any power in controlling the processes determining $-dSe$. The parts can only assume and hope that the upper level – the whole which they belong to – will remain stable. An overview of this organization is given in figure 2.

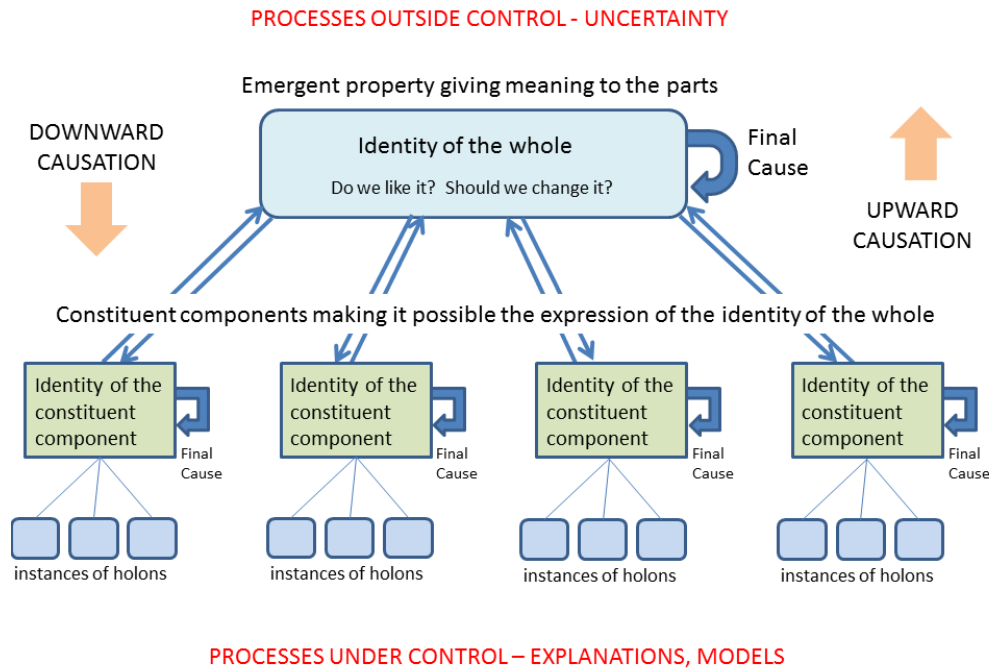


Fig. 2 The relational analysis of the organization of the identity of a social system made up of constituent components

The success (or failure) of maintaining the evolving set of identities of both the whole and its constituent components, across different hierarchical levels, represents the principle of so-called truth that validates the information used in the semiotic process. In a holarchy, identity is defined through a sharing of power between upward and downward causation. The shared definition of identity has been called “equipollence” (Iberall, Soodak, and Arensburg 1981), complexification harmony (Goldberger 1997), double asymmetry (Greene 1969), and holarchic health (Waltner-Toews 2001).

With this framework, it is possible to redefine the challenge of ensuring quality and integrity in science as part of the semiotic process of human societies. Human societies are made of constituent components that express awareness and reflexivity across different hierarchical levels (individuals, households, communities, countries, macro-institutional arrangements). Social constituent components have to stabilize at the same time: (i) their own identity; and (ii) the identity of the larger whole to which they belong. In a system organized in holarchies, components experience an internal yin-yang tension when coming to the definition of their final cause¹. In the analysis of social systems, what is good for households – not paying taxes – is bad for the administrative units (e.g. the town or the country) to which the households belong, and vice versa. The perception of “paying taxes” is ambivalent – it can be perceived as “a very bad choice” by a household that does not have enough income after tax to guarantee a decent quality of life to the children, it can be perceived as “a very good choice” by a wealthy household

¹ It may be observed that Freud has also proposed the co-existence of conflicting definitions of “the self”: one coming from the inside (the id), one coming from the outside (the superego), and one integrating in a compromise the two views (the ego).

living in a wealthy country with a high quality public welfare system. This example shows that contrasting perceptions are not only determined by the definition of different typologies of constituent component – e.g. a household vs the mayor of a town – but also by the context – e.g. the context of the instance of household and instance of town.

3. The role of science in the semiotic process of society

In this section we discuss the role of science as constituting the step of “represent” in the semiotic process. In complex systems, representation needs to occur at multiple scales: the representation of the whole is non-equivalent to the representation of the constituent components, which can be represented as functional or structural components. We use the concept of narrative to distinguish between the multiple representations used in social systems. Following the literature on semiotics, we argue that representations are not objective, or observer-independent, accounts of observables, but are the embodiment of a narrative.

We distinguish among three types of narratives:

1. Justification narratives about the identity of the system as a whole

Justification narratives are typically concerned with the implications of the dependence of the system on external boundary conditions (outside of human control) and the potential external and internal threats to the stability of these boundary conditions. Justification narratives are based on a continuous monitoring and a permanent process of adjustment. At this level, decisions deal with the “tragedy of change” at the level of the whole (Funtowicz and Ravetz 1990). In the limiting case, the decision to be made is about the bifurcation: (i) try to solve problems with adaptive changes – adjusting the identity of the constituent components and existing controls; or (ii) look for something else through a major re-shuffling of both the identity of the whole and the relative size of constituent components leading to a different shared perception of the identity of the whole: a revolution in the institutional setting of society. This type of narratives provides a set of attributes associated with the identity of the whole and of its constituent components. Justification narratives define “what the system is”, an operational definition of “the self”, and in social systems this translates into defining “who we are” and how “we” understand our belonging to the whole. The problem with choosing these narratives lies in the fact that human systems are reflexive systems: there are always several legitimate but contrasting narratives about the identity of the self at the level of “constituent components” and their relationship with the identity of the self at the level of the whole.

2. Normative narratives about how to improve the constituent components.

Normative narratives define what has to be done to improve the performance of the constituent components while maintaining the identity of the whole. The implementation of these narratives implies the creation of winners and losers in the re-definition and negotiation of the final causes of the various constituent components and of the definition of the final cause of the whole. At this level, decisions are needed in order to deal with the “tragedy of change” at the level of the constituent component. When dealing with the tragedy of change and what should be preserved at which cost, normative narratives assess the implications of adaptive changes:

which constituent components should be changed and how? Who is affected and how by a change in constituent components? If important threats are perceived, what action should be taken? How to handle the unavoidable presence of conflicts inside society? The choice and implementation of normative narratives is associated with political conflicts.

3. Explanatory narratives used to develop anticipatory models

Explanatory narratives are associated with the scientific enquiry and the organization of explanations and representations recorded by scientific knowledge. These narratives utilize predefined disciplinary descriptive domains (determined by a pre-analytical choice of a scale and a dimension of analysis) in which models can be developed to gain anticipation. They constitute a fragmented information space, in continuous expansion. Society has to provide a continuous process of validation and selection of this body of knowledge that is used to inform the discussion of policies inside the semiotic process.

This last type of narrative no longer refers to the social system itself. The narratives used in science do not require or imply reflexivity and therefore "the self" is not included in the models. Scientific analysis does not address the unavoidable existence of the tragedy of change that affects both the whole system and its constituent components. Scientific representations assume that:

- (i) the definition of the identity of the social-ecological system – the justification narrative associated with the final cause used to define the explanatory narrative as relevant and the model as useful – is assumed to be uncontested; and
- (ii) the definition of normative criteria that are used to prescribe changes in the constituent components (implying winners and losers) are assumed to be uncontested.

The limits of the contribution of scientific narratives to the semiotic process

As a simplified heuristic, we compare the elements used to realize the semiotic process in EU countries: (i) before the European Union, before the internet and social media; and (ii) after the European Union, in an increasingly globalized economy. With this simplified account we do not mean to provide an accurate historical reading, nor to romanticize the past. We use this simple comparison as a heuristic to discuss how issues of identity may be understood in a social system. We start this comparison with a reflection about the reasons that may convince a citizen to be brave when handling with the tragedy of change. If citizens were required to do the extreme sacrifice of their lives for their country (an event that occurred very often in the last 500 years in Europe), the question to be answered would be, why should instances of constituent components die to preserve the identity of the whole to which they belong? The difference between the situation experienced by people that lived in European countries in the past and EU citizens living in the Union now is described in the two figures: Fig. 3 and Fig. 4.

LEVEL n	EU countries 1450-1950	EU 2010 - ?
	<i>The representation of the whole - the system against its context</i>	
	JUSTIFICATION ABOUT THE IDENTITY	
WHAT do "we" want to preserve	OUR HOMELAND OUR KING OUR KIND <i>"SOMETHING" AN INSTANCE</i> <i>* clear definition based on observable</i> <i>* definition reflecting history and place</i>	PEACE FREEDOM JUSTICE WELFARE <i>EXPECTED ATTRIBUTES OF PERFORMANCE</i> <i>* relational definitions different for different people</i> <i>* relational definitions context dependent</i>
HOW do "we" want to preserve it	WITH OUR WEAPONS WITH OUR LIVES USING OUR WISDOM <i>* Self-referential using internal means</i> <i>* Self-referential assuming shared passion</i>	GLOBAL MARKET INNOVATIONS MORE PRODUCTIVITY * (* BY PRODUCING MORE SURPLUS) <i>* Depending on external processes outside control</i> <i>* Internal factors are irrelevant without external factors</i>

Fig. 3 Justification narrative at the level of the whole: comparison EU individual countries 1450-1950 and EU 2010-?

In Fig. 3 different justification narratives are examined at the level of the whole: *what* do "we" want to preserve, and *how* do "we" want to preserve it. In Fig. 4 the same questions are posed at the level of constituent components to compare normative narratives. The two definitions of "we" both at the level of the whole and at the level of the constituent components should be kept in congruence with each other.

LEVEL n-1	EU countries 1450-1950	EU 2010 - ?
	<i>The agency of constituent components - the system against its parts</i>	
	Choice of NORMATIVE CRITERIA	
	Our economy	The global market
WHAT do we want to preserve	<p>SPECIFIC INSTANCES OF STRUCTURAL AND FUNCTIONAL ELEMENTS OPERATING IN A GIVEN PHYSICAL PLACE</p> <p><i>Normative Criteria to be negotiated among instances of constituent components</i></p>	<p>STABILIZATION OF AN INTEGRATED SET OF FUNCTIONS EXPRESSED WHO-KNOWS-WHERE BY WHO-KNOWS-WHOM</p> <p><i>Normative Criteria influenced by instances of "GHOST" constituent components*</i></p> <p>* LOBBIES</p>
HOW do we want to preserve it	<p>STRATEGIES CONTEXTUALIZED IN HISTORY AND PLACE</p> <p><i>Choices are validated through deliberations among constituent components</i></p>	<p>OPTIMIZING "PERFORMANCE PROFILES" BASED ON A FINITE SET OF ATTRIBUTES ASSUMED TO BE UNIVERSALLY APPLICABLE</p> <p><i>Choices defined by appointed expert committees using scientific evidence and road maps</i></p>

Fig. 4 Justification narrative at the level of the whole: comparison EU individual countries 1450-1950 and EU 2010-?

This comparison suggests that the task of keeping coherence over the two definitions of "we" across levels was easier in the past. In the past, the identity of the whole was associated with signs related to a specific icon of the whole – our king, our homeland, our kind (left side of figure 3). In this situation, the continuity of the individuality – France in 1750 was still France in 1950 even though its structural and functional elements were totally different – was guaranteed by the way used by France (and French people) to preserve beliefs, purposes, and values. This continuity was also reinforced by the tangible and spatial definition of the constituent components – i.e. French provinces, cities, household types. On the contrary, when looking at what is proposed to EU citizens today, there is nothing tangible or directly controlled by EU citizens that can be used to define their own identity across the two levels (the whole and the constituent components), or to decide what to retain and what to lose in the original identity when becoming something else. The identity of the whole is associated with a set of semantically ambiguous attributes (peace, justice, welfare) and the strategy to defend this identity is left to the agency of the market, human ingenuity and technical progress. There is little that can give EU citizens a feeling of empowerment in relation to their agency to protect the whole to which they belong. Citizens became consumers.

The situation is even more ambiguous at the constituent component level (see figure 4). EU citizens now are no longer identifiable with specific realizations of constituent components. They are consumers whose necessities are guaranteed by the proper functioning of the global market in which functional and structural elements cannot be clearly identified. This may explain

the continuous need felt by the new generation of EU citizens to take pictures of themselves in order to have something reassuring them in relation to their identity.

The evidence-based policy approach seems to be based on the assumption that it is possible to define road map towards progress based on a generic definition of performance that does not require a contextualization in relation to the special identity of the society in which it is applied. As a consequence, normative narratives are excluded from scientific discussion and are naturalized as assumptions in scientific narratives, through an institutional process of conflation of the technical and the social, as captured by the concept of socio-technical imaginaries (Jasanoff and Kim 2009). The big difference between the situation in the past and the situation now is that the semiotic process in the past involved directly the various instances of constituent components in the discussion of how to deal with the tragedy of change. On the contrary, a policy making based on rationality imagines that it is possible for a committee of experts and other elected or not-elected functionaries without "skin in the game" (Taleb 2018) to decide which normative narrative should be used to change the identity of special instances.

The post-truth world as a crisis of the semiotic process of science and the inability of modern societies to cope with the tragedy of change

Science works well when it provides the semiotic process an input of information useful to achieve semantic closure. Semantic closure can be associated with the concept of correspondence in philosophy of science, which is used to define truth. That is, a statement is considered true if it corresponds with the shared perception of the external world. However, modern science can only guarantee truth by fixing both the type of observer and the type of observation in time, abstracting from the special characteristics and the becoming of instances. In complex adaptive systems, the definition of relevance and usefulness of observations need to be constantly updated and the identity of the observer is constantly changing. We argue that modern science, by focusing only on explanatory narratives and by excluding by default the implications of the pre-analytical discussion of justification and normative narratives, cannot contribute to an effective update of the semiotic process considered as a whole. By focusing exclusively on "how" questions, science is not capable of addressing the associated "why" questions. This means that the information provided by science is useful only in the short run and when applied to specific issues, as long as the identity of the whole and the identity of the constituent components remains the same. Whenever faced with the tragedy of change, modern science cannot provide semiotic closure. This is the key implication of Post-Normal Science (Funtowicz and Ravetz, 1990; 1993; Funtowicz et al. 1998).

In the context of complex adaptive systems, decision making is not just about solving local problems, but has to deal with the following questions related to the evolution of the identity of both the systems and the survival of the instances of its constituent components:

- *How to make decisions under uncertainty?
- *How to handle stress caused by uncertainty and by changes of identity? How to act when facing painful and risky decisions regarding changes in the identity of constituent components?
- * How to decide which beliefs and purposes have to be preserved if the decisions lead to contrasting effects on the (dual) identity of the whole and of the constituent components?

We believe that in relation to these set of question the knowledge associated with rationality has very little to contribute. The tragedy of change requires updating the identity of the self. The semiotic process does not deal with the preservation of "types" (what is observed by science) but rather with the survival of the "instance" through adaptation. The key questions escape the realm of modern scientific inquiry: How do we know who is "we"? What should "we" believe in? When faced with change and adaptation, everything becomes special. The self is a given instance and at the same time a negotiated identity. In this situation intuition or faith can be as useful as recorded experience (especially when dealing with first time events) in guiding decision making.

In the last years, and especially after the negative effect of the economic crises and stagnation on the European welfare state, an increasing fraction of people no longer trust the story-telling of the elites in power. As a consequence of this loss of trust in the elites of experts and policy-makers, more and more people do not trust the main narratives endorsed by the scientific establishment. The reciprocal legitimation that followed in Western countries the successful validation of the enlightenment in the semiotic process (when science replaced religion in its role of legitimization of the establishment) is quickly reverting to a reciprocal de-legitimation in the first decades of the third millennium. The crisis of legitimacy of the establishment, identified as post-truth politics, is destabilizing science.

4. Quality and integrity of science in the semiotic process

Drawing from the understanding of society as a complex adaptive, becoming and anticipatory system, and building on the description of the role of science as part of the semiotic process through which societies maintain their identity, we now turn to our out-of-the-box discussion of *integrity* and *quality* in science.

The concept of integrity can be associated with the capacity of a semiotic process to produce useful meanings that preserve the identity of an autopoietic system through its process of becoming in time. The feeling of living in a post-truth world signals the failure of the semiotic process in guaranteeing an effective update of the integrated set of identities expressed by a socio-economic system. This failure is associated with the emergence of a crisis in the step *represent* (scientific inquiry). The symptoms are well known: scientific misconduct (production of invalid signs), the reproducibility and retraction crises (corruption of the process used to generate meaningful signs), and public mistrust (loss of confidence of the interpretant in the proposed signs). The representation provided by science is no longer useful for society and the validation provided by society to the information used to guide action is no longer useful for science.

Because of disciplinary specialization, science provides partial analyses, that can be very accurate but that can only be used to explain one problem at the time. As soon science (especially quantitative science) is forced to deal with complex issues – e.g. the nexus and the sustainability of economic growth – in which information has to be handled in a coherent way across scales and not just across dimensions, the existence of these limits becomes clear. The persistent ambiguity of the meaning of the term nexus in relation to policy and sustainability (Cairns & Krzywoszynska 2016; Giampietro, 2018) is a recent example of the limits of science.

Quality can be defined in different ways and at different levels of the semiotic process. At the level of the whole, quality has to do with the ability of preserving a shared definition of the identity of the whole and a satisficing definition of purposes. Purposes may need to be updated because of the accumulation of experience and/or because of the insurgence of new feelings. At the level of components, quality of information may be expressed as fitness for purpose (Funtowicz and Ravetz 1992). This definition of quality takes a pragmatic approach that is compatible with changes in purposes and identity.

In the field of semiotics, a crucial element in the construction of signs is the interpretant for which the sign is meant. For example, walking sticks base their survival strategy on their iconicity to twigs. How predators see (or fail to see) them matters vitally in the sign process through which walking sticks interact with the world (Kohn 2013). The quality of the representation (similarity to twigs) is decided by the semiotic process. If the similarity is correctly interpreted by predators (interpretant), walking sticks will not to be eaten. Semiotic processes are highly contextual, as the iconicity of walking sticks depends on them being in a forest. Quality is defined in relation to the interpretant.

The key role of the interpretant in the semiotic process is at odds with the conception of quality as objectivity in modern science. Disciplinary science requires for scientists to be types. This explains why scientists are not expected to use the first person in orthodox scientific papers. The expression "I know very well" is considered to be not scientific, scientist have to use the expression "it is well known". Scientists cannot be instances (Dr. Smith), they must be typologies of story-tellers (e.g. reputable biologist) that describe the expected interactions of typologies of agents using a set of attributes determined by the disciplinary story-telling. Accepting this framing entails that later on the scientific output must be used only by the expected typologies of interpretants! For this reason the attribute "beautiful" is very rarely used in scientific representations. Models are used to generate explanations and predictions whose usefulness depends on the validity of the narrative within which they have been generated. This means that there is no possibility of checking the usefulness of models from inside the discipline that generated them. One has to check their usefulness with those using the models for guiding action. The post-truth society can be explained by a progressive lack of coherence in the coupling of scientific narrators (those generating the representations) and the interpretants of the representations (those that use the chosen narratives for guiding action).

Konig et al. (2017) contrast the norms of quality in science with examples of misconduct. This exercise shows how quality standards are associated with types, while problems emerge in the behaviour of instances. For example, transparency is considered a norm of quality in science. However, its opposite, defined as hiding interests and intentions, can only be attributed to a specific scientist (an instance), not to a discipline or an abstract scientific community. With regard to best practices, trans-disciplinarity is seen as a potential solution to the partial view of disciplinary silos. Indeed trans-disciplinarity requires integrating many-to-one mappings – non-equivalent typologies of representations describing the same instance. However, when contributing to transdisciplinary processes instance of scientists are still trapped in the typologies of perceptions and representations of their original disciplinary approach. For this reason, transdisciplinarity is very challenging in practice.

The analysis of the semiotic process shows that decisions that affect the evolution of societies are taken by *instances* (people having skin in the game). These instances have interests, agendas, normative values and points of view. This obvious fact should be acknowledged and dealt with in the process of production and use of science for governance. This is the challenge proposed by Post-Normal Science (Funtowicz and Ravetz, 1993). Scientists are just another typology of agents and instances involved in the semiotic process, and for this reason they are affected by the dualities: "instance/type" and "the self/the other". These dualities entail the need to go through the tragedy of change in the process of becoming. The systemic exclusion of "the self" – both in terms of constituent component defining the purpose of the analysis and in terms of the scientist carrying out the analysis – from scientific models, limits the possibility of assessing quality and integrity in science.

5. Conclusion

In conclusion, in order to properly use the scientific input in the semiotic process it is essential to critically reflect on what type of input can be given by science and what type of inputs cannot be given. Being critical is not about being pro science (doing marches to protect the enlightenment against the "endarkment") or being against science (promoting superstition and witchery). The discussion is totally different. The emergence of the post-truth debate suggests that large parts of society feel that the scientific inputs used in the process of decision making at the moment does not have semiotic closure. Intoxicated by the promises and the success of the enlightenment, modern societies may have attributed to science powers that it does not have. According to this analysis, it is obvious that this crisis is not a fault of scientific inquiry, but it urges a reflection of how science is used in the semiotic process.

We argue that semiotic closure requires the ability of integrating explanatory narratives in relation to the re-discussion of the identity of the self: addressing the implications of the tragedy of change. Modern science provides no cosmological vision, except for the contradictory explanation of the big bang (before which there was no time) generating an expanding universe (outside which there is no space), but no information about the complex relation of "the self" with "the other".

Information associated with rationality or the agreement on a set of shared ethical guiding principles does not cover all the types of information required to operate the semiotic process. When considering the identity of Japan in 2018 and Japan in 1518, one can conclude that Japan did not retain in its identity the same rational explanations nor normative narratives of 500 years ago. So what type of attributes of the identity of Japan remained in its evolutionary path? These attributes are not directly considered in scientific analysis, especially in quantitative analysis: (i) a shared feeling of belonging to something superior to the constituent component; (ii) shared symbols of identity translating into a commitment and responsibility to achieve a common set of goals; and (iii) the modalities used to deal with the tragedy of change through the semiotic process (including re-starting from scratch after the Second World War). This type of information essential for a semiotic process is not generated by modern scientific inquiry.

Science can overcome the crisis of trust only through a restoration of the integrity of the semiotic process. In order to be able to receive effective feed-backs from the society, science should be used to structure the debate about controversial topics, to make sense of multiple

non-equivalent representations of the same issue, to acknowledge and use uncertainty and complexity. This requires a move from a substantive use of science as a source of *facts about the world*, to a more reflexive use of science as a process making sense of information useful to *handle the stress associated with a continuous update of the identity of the self*.

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