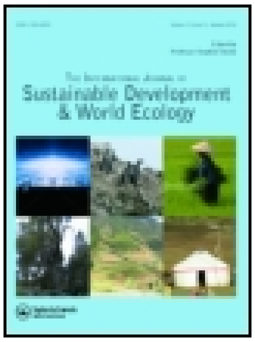

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An epistemology for sustainability science: a proposal for the study of the health/disease phenomenon

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Epistemological approaches in classical science were grounded on the explanatory needs of the phenomena of their historical time. Nevertheless, our contemporary world shows challenging situations in which the explanatory models of normal sciences have not proved effective. One of these fields is the area of health, in which the complexity of pathological phenomena continuously overwhelms the capacity of the classical models of biomedical research to provide effective answers regarding their comprehension, prevention and control. In the last decade a new science of sustainability has emerged, grounded in general systems theory and the conceptual basis of sustainable development. This area has become a scientific possibility for transcending reductionist analyses of classical sciences, by means of systemic comprehension of contemporary phenomena within the economic, social, environmental, political and ecological domains. However, the literature shows few specific references to an epistemological approach that may establish the boundaries for a metatheoretical structure on which knowledge can be generated in the framework of this emerging scientific discipline. This paper proposes an epistemological model for analysis of the health–disease phenomenon from the point of view of sustainability science.

Keywords: epistemology; health/disease relationship; science; study object; sustainability

Introduction

Epistemology is the discipline of verification and logical confirmation of the explanatory structure of scientific theories, and its primary objective is to guarantee the undoubted safety of scientific methods and knowledge (Lenk 1988). Therefore, its goals can be briefly defined as monitoring and evaluation of the construction of scientific concepts, the scientific theories derived from these, and foundations allowing for the construction of demonstrative methods based on these theories. The epistemological reflection fulfils two basic tasks: a critical task, in which scientific practices are examined and evaluated, and a propositive task that, parallel to applied scientific practices, searches for alternatives in order to provide solutions to scientific challenges.

Scientific theories within the field of normal sciences are in a process of constant evolution, as Kuhn appropriately indicated in *The Structure of Scientific Revolutions*. According to Kuhn (1970), a paradigmatic change in a scientific discipline is bound to the appearance of new theories that will account for the phenomena connected to the affected discipline's object of study in a more suitable way. Some of such theories are traceable to previous theories, and may be understood as their evolution; others are completely new but hold an imprint of past theories, as there can be no radical rupture from a previous paradigm. Within the context of normal sciences, a state-of-the-art scientific theory requires the existence of an explanatory model that is held to be consistent enough to account for the issues that may arise within a particular field of knowledge in relation to its object of study. Nevertheless, taking into consideration the inner dynamics of the reality from which scientific disciplines obtain their data, these explanatory models progressively lose their resolutory capacity and, consequently, new theories with a greater explanatory potential emerge. These new theories provide solutions not only for the phenomena that the prior model already accounted for, but also for the new approaches or viewpoints that a problematic reality demands from the discipline.

Classical epistemological approaches responded to the explanatory needs of the phenomenal reality of their historical present. However, nowadays science faces problematic situations in which the explanatory models provided by normal sciences have proved inadequate, or have shown little resolutory capacity. One of these areas is health, in which the growing morbidity–mortality caused by infectious diseases is overwhelming biomedical researchers' capacity to provide responses that prove effective for prevention and control following classical models. As a result, despite the fact that the sum of knowledge created by the biomedical model, grounded on a Cartesian conception of health, has increased exponentially in the last decades, the amount of the population affected by health problems has also expanded dramatically. A clear example can be observed in Prothero (2002), in which the author provides evidence for the existence of a direct relation between migrant populations and the incidence of malaria, as well as of the infectious parasites' resistance to medical

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treatment and the effectiveness of prevention and control strategies implemented. In fact, socioeconomic, cultural, ecological and political issues influence the symptomatic presentation of a disease by means of its effect on the mobility of populations at risk. As the author concludes in his paper:

> 'This context requires the attention of social scientists as parasites and vectors require that of malariologists and entomologists. More is needed to clarify and develop relationships between biomedical and social sciences so that existing *multidisciplinary* approaches become truly *interdisciplinary* . . . Many advances in biomedicine are made in laboratories, population movements and other human factors must be studied and evaluated only in the field, and it is in the field that advances in biomedicine have to be applied to make an impact on health hazards on a large scale. Complementary relationships between the biomedical and social sciences are needed to take account of the ecological, cultural and socioeconomic contexts in which malaria, HIV/AIDS and other health hazards occur.' (Prothero 2002: 31)

From the point of view of the health/disease relationship, this situation may be comprehended as complex phenomena showing the increasing complexity of the varied phenomena of contemporary reality. For this reason, the complexity posed by contemporary challenges overwhelms the reductionist explanatory models offered by disciplines grounded on the Cartesian epistemological model. Prothero (2002), quoting Bradley, argues: 'We are notoriously poor in tackling complex problems holistically.'

In the last decade, a global scientific trend has asked for the constitution of a new sustainability science, which is to be conceived as an emerging field of knowledge that embodies the scientific possibility of transcending the reductionist analyses of classical sciences by means of a systemic understanding of contemporary phenomena, both in economic and social spheres and in environmental, political and ecological areas. The science of sustainability focuses on the dynamic interactions between nature and society, and is grounded on the principle that the efforts to know the individual elements of the nature-society system in an isolated way prevent the observer from comprehending the whole of the system itself:

> 'Perhaps the strongest message to emerge from dialogues induced by the Johannesburg Summit was that the research community needs to complement its historic role in identifying problems of sustainability with a greater willingness to join with the development and other communities to work on practical solutions to those problems. This means bringing our Science and Technology to bear on the highest-priority goals of a sustainability transition, with those goals defined not by scientists alone but rather through a dialogue between scientists and the people engaged in the practice of 'meeting human needs while conserving the Earth's life support systems and reducing hunger and poverty'. . . Sustainability science is not yet an autonomous field or discipline, but rather a vibrant arena that is bringing together scholarship and practice, global and local perspectives from north and south, and disciplines across the natural and social sciences, engineering, and medicine.' (Clark and Dickson 2003: 8059–8061)

Sustainability science shares the same basic conceptual structure attributed to sustainable development by the numerous political and academic addressees on the subject, starting from the Brundtland Report and including the Rio and Johannesburg summits. This conceptual structure shows the interrelationship between three dimensions of reality: the social, the ecological and the environmental, framed by an institutional dimension that conveys an ontological status to this relationship. Besides, it is also conditioned by a number of diverse conceptions depending on the conceptual interpretation, the social and political contexts, and the scientific dimension from which the factual phenomena are observed and analysed. (Ríos et al. 2005). Despite the fact that scarce reference to the characteristics of this new science can be found in the literature – such as interdisciplinarity, its foundation on a holistic perception of reality and collaboration in scientific research – scarce reference is found to the epistemological fundamentals of this new science. These references are mostly limited to a conceptual relationship with the general systems theory or, in some cases, with a philosophical approach to the reconciliation of C.P. Snow's two cultures as a foundation stone for sustainability science. Therefore, there have been no specific references to an epistemological approach that could establish the boundaries of a metatheoretical structure on which knowledge can be generated within the framework of this emerging scientific discipline.

This paper aims at providing an updated revision of these 'new epistemologies', understanding their novelty as the fact that they are theoretical proposals that introduce an epistemological shift in the conception of the phenomenal reality, while taking into account suggested changes in the relation subject–object. Then, from that theoretical standpoint, a new epistemological model for sustainability science based on these new epistemologies is presented within the context of the analysis of the health–disease relationship. The health–disease relationship has become a complex scientific problem that transcends Cartesian models of research underlying the current biomedical model (Fleck 1979; Capra 1984, in the case of syphilis).

Methods and constructs

In the field of twentieth century philosophy of science we can distinguish several theoretical constructs that show relevant differences from the Cartesian model; two of the most representative proposals are the general systems theory (GST) and the complex systems theory, which have established a basis for the development of disciplines such as ecology and the new biology.

General systems theory

General systems theory is firmly grounded on the Aristotelian tenet that establishes that *the whole is more than the sum of its parts*, which is to be found in his *Metaphysica*. This postulate was purposely ignored in the process of construction of epistemological models of

Western scientific disciplines, which, according to the Cartesian model, advocated the fragmentation of phenomena into their minimal parts in order to be comprehended separately. Nevertheless, during the 1920s, the Austrian biologist Ludwig Von Bertalanffy proposed the GST in the course of his research on 'open systems'. It was with his works that the Aristotelian approach was resumed and applied to areas of epistemology and methodology, despite the fact that Blaise Pascal had already meditated on the Aristotelian tenet from an epistemic point of view – as may be appreciated in his statement 'I hold it equally impossible to know the parts without knowing the whole and to know the whole without knowing the parts in detail' (Morín 2001: 123), it was Bertalanffy who gave new life to the Aristotelian approach:

> 'Since the fundamental character of the living thing is its organization, the customary investigation of the single parts and processes cannot provide a complete explanation of the vital phenomena. This investigation gives us no information about the coordination of parts and processes. Thus the chief task of biology must be to discover the laws of biological systems (at all levels of organization). We believe that the attempts to find a foundation for theoretical biology point at a fundamental change in the world picture. This view, considered as a method of investigation, we shall call "*organismic biology*" and, as an attempt at an explanation, "*the system theory of the organism*".' (Klir 1972: 24–25)

This is the basic premise of GST, which was initially conceived for biology. However, if we substitute the concept of *the organic* by that of *organized entities*, the term acquires a general character that is applicable to other contexts. In Bertalanffy's words:

> 'The properties and modes of action of higher levels are not explicable by the summation of the properties and modes of action of their components *taken in isolation*. If, however, we know the *ensembl*e of the components and the *relations existing between them*, then the higher levels are derivable from the components.' (Klir 1972: 25)

Systems theory may be considered as a new way of conceiving reality in which, contrary to the analytic model of classical science, systems are also to be understood as a different 'way of seeing'. Despite some controversy generated on the issue, GST is not to be regarded as a scientific discipline. For the purpose of this paper, systems theory's most outstanding feature lies in its metatheoretical character, which is precisely what makes it so relevant for the development of an autonomous epistemology for sustainability. For this reason, in our view, GST must be regarded as a scientific approach rather than as a scientific discipline.

According to Bertalanffy, a system is described as a set of elements related both among themselves and to their environment, or as a model that aims at a conceptual representation of universal characters of observable entities (Bertalanffy 1972). The major differences from traditional scientific disciplines, also built on conceptual models, derive from the fact that systems refer to general conceptual phenomenal models that are not particularized into independent elements. Therefore, systems theory is essentially interdisciplinary/transdisciplinary, as it is grounded on the contribution of particular sciences created for the observation and analysis of the divisible parts of a phenomenon, but it goes further to transcend the level of separate disciplines and unites them within a holistic approach. The original theory posed by Bertalanffy suffered modifications during the twentieth century. Especially relevant to this study is Von Foerster's System Dynamics Theory because of its significance for sustainability. Von Foerster introduced a temporal dimension into GST, so that temporal variation must be taken into account in the analysis of systems. This theory is closely linked to the concept of stability, i.e. how a system reacts to disturbance. In this sense, the theory proposes two methods for systemic description: first, an internal one, which corresponds to the classical systems theory and which is more closely related to the mathematic conception of the system's internal stability; second, the external description method focuses on the relations between the system and its environment, as well as with other systems, and analyses the information exchange within the system and with its surroundings, taking their temporal variations into consideration. Von Foerster's particular methodology was used for the creation of future scenarios of the Massachusetts Institute of Technology (MIT), at the request of the Club of Rome, in the document known as *The Limits to Growth*, which marked the beginning of debates leading to the emergence of sustainability as an area of knowledge.

Epistemological premises for systems theory

From the viewpoint of the philosophy of science, reality can basically be framed into two types of systems: real and conceptual. Real systems deal with the systemic elements of reality that can be comprehended by the senses. In contrast, conceptual systems include symbolical constructions, such as mathematics, logic and knowledge generated by science, which are themselves constructed by conceptual systems built upon reality (abstracted systems). Contrary to the subject–object relation, in systems theory the object loses the sense it receives in classical science and acquires a systemic character, which is only comprehensible by observing the interrelations between the elements that make up the system. As to the subject, sensory perception, which in classical sciences defines the generation of knowledge about the object, lacks epistemological validity in systems theory because, in Bertalanffy's words:

> 'Perception is not a reflection of "real things" (whatever their metaphysical status), and knowledge not a simple approximation to "truth" or "reality". It is an interaction between knower and known, and thus dependent on a multiplicity of factors of a biological, psychological, cultural, and linguistic nature.' (Klir 1972: 37–38)

The subject generates knowledge as long as it establishes a relation with the object (system), and that knowledge-generating relationship is a highly complex one, as it conceives the multidimensionality of the object-system, and forces the subject to increase and diversify the degrees of observation, as the object is observed within the context of scientific disciplines that provide tools for measuring its dimensions.

Methodological principles

From a methodological point of view, and regarding scientific areas, systems involve two main tasks: first, to understand the systemic condition of the observed phenomena, we must recognize the relationships among the system elements, and define the hierarchical organization of the relations found, at different levels, in order to identify possible subsystems within the problematic system analysed. This procedure allows for the comprehension of the effects that variations in one of the system elements may cause on the whole, as the relations established by this element inside the system are already known (Gallopin 2001). As a result of the abovementioned process, the second task is to understand the system's own dynamics. From this perspective, the Cartesian model is transcended, because the most fundamental task is not only to know the elements of the system and their relationships, but to understand the dynamics of those relationships both inside the system and outside it, in its relation to the environment and to other systems with which it interacts. Nevertheless, it is important to note that the Cartesian model is transcended, but not abolished.

Complex systems

According to our previous arguments, GST within the domain of sciences must be acknowledged as an epistemological tendency that has helped overcome the Cartesian level of fragmentation of reality and the logical explanation of the organization of system elements according to mathematical models. Therefore, to comprehend a system completely is to grasp a phenomenon of reality in a much more holistic way. However, the systemic approach in itself does not imply a new dimension to the epistemological, as systems can be equally observed from a single perspective, i.e. from the point of view of a certain discipline. For that reason, when we deal with the domain of systems it is necessary to be precise about the type of systems with which we are working. According to Gallopin, systems may offer three levels of complexity: first, there are simple systems, which can be 'analysed' from a single perspective – and a single discipline – and which can be studied with standard models. These models alone provide a satisfactory answer to problems generated inside this systemic category. Second, complicated systems are those in which it is not possible to carry out a comprehensive approach following a standard model. However, in the near future, new computer technologies and simulation and statistical analysis software will surely become a useful tool that may well let these complicated systems be unidisciplinarily comprehended. Finally, complex systems, despite sharing the difficulty of being comprehended by standard models with complicated systems, differ from them in the fact that they require at least a minimum of two disciplinary perspectives to be comprehended, described and typified. By definition, complex systems do not necessarily imply a larger number of elements and relationships; rather, they present a wider range of 'attributes' than that offered by simple and complicated systems when analysed.

Attributes of complex systems

Some of the most relevant attributes of complex systems, which help differentiate them from other types of systems, are (Gallopin 2001):

Multiplicity of legitimate perspectives. This multiplicity of perspectives involves the joint contribution of the different perspectives from which a systemic problematic phenomenon is perceived while in the process of solution searching. It requires assuming the different contexts from which the phenomenon can be comprehended. Simultaneously, these contexts are to be inherently found in its definition.

Non-linearity. Complex systems are non-linear entities, i.e. there is no direct proportionality between the magnitude of a variable in a system and its effect on its stability. Therefore, complex systems present a dynamic variation of the system rather than a linear relation of a cause-effect type.

Emergency. This property refers to the operationalization of the Aristotelian tenet on which GST is grounded. As a consequence, the properties of the parts of a system are only comprehensible in the context of the system itself, and the latter cannot be grasped just by knowing the independent features of their components separately. Therefore, the focus of analysis within the system is not the properties of the parts, but the interactions that occur between them.

Self-organization. By self-organization, Gallopin refers to the quality that characterizes the cooperation between the components of a system in order to create organized macrostructures possessing autonomous behaviour. The literature shows references to emerging structures as an outcome of the relations among components of a system. These parts show a macroscopic order generated from an apparent state of 'disorder' in the relations inside a complex system. These emergent structures are known as 'fractals', and they do coincide with critical points or phase transitions in which the boundary between order and disorder appears. It is these points that provide the unique identity to complex systems (Solé et al. 1996: 14–21).

Multiple scales. This attribute refers to the existence of a hierarchical order between the elements of a system and, therefore, between the relationships established within its boundaries. Different levels can be found, so that lower degree subsystems appear, and these can be, in turn, subsystems that integrate systems of larger importance (supra-systems). This is one of the most demanding characteristics to be analysed in complex systems, for, in order to be comprehended, it is necessary to ascertain the relationships among the components at different levels of the systems (sub-levels), but, at the same time, it is indispensable to know the relationships between the different levels of the suprasystem. Quite evidently, this situation exemplifies the uncertainty inherent to complex systems.

Irreducible uncertainty. Several situations may generate uncertainty within a complex system, such as an incomplete comprehension of a system or the lack of information concerning both the elements of the system and their relationships. Nevertheless, some other situations may generate an uncertainty that can be described as 'irreducible'; this is the case of non-linear processes in the generation of self-organization in the system. These processes lead to an unpredictability that becomes inherent to the system's behaviour. Similarly, irreducible uncertainty appears when we deal with human or institutional systems and subsystems, which can self-analyse and create new types of relationships among themselves, virtually impossible to be predicted, as a response to new situations. Finally, human systems present another source of relevant uncertainty, especially in cases in which human observation of the relationship between system components is required as a source of information about them, in a process similar to that shown by Heisenberg's uncertainty principle at the level of micro-particles.

Epistemological theories for sustainability science

Some of the contemporary epistemological theories may be representative of the emergence of new approaches to the subject–object relationship from the point of view of GST, information and communication theory (ICT) and the concept of complex systems. For that reason, in this section we will review them briefly, in order to suggest possible applications of these theories to the context of sustainability science.

Transactional epistemology

Transactional epistemology (Buckley 1972) is a theoretical model that perceives the process of knowledge generation as an information flow based on the acquisition of information from the physical and social environments. This information, captured by a receiver, is transformed, codified and processed through sensory, linguistic and cognitive mechanisms, to be later reprocessed by decision-making and response-generating mechanisms. After that, information returns to the physical and social environment, together with the application of the measures generated in the processes and, as a result, a transformation of this environment is provoked. In this epistemological proposal both GST and Shannon's ICT are applied. It shows a number of basic epistemological premises that allow for the comprehension both of its fundamental principles and of its possible applications (Buckley 1972):

(1) The information flow, which serves as the basis for the model, is limited to the interior of a system. As such, it has to be assumed totally in the process of data capture, transformation, codification and processing, because these processes are affected by feedback at different locations and at different times. Consequently, the kind of information grasped is affected by the receiver's attitudes and interests.

(2) The comprehensive performance of the system as a 'transactional' one implies that the knowledge generated is not a product of a passive process of data reception, but a construction and reconstruction of knowledge based on a continuous exchange between the individual and his physical and social environment, requiring the permanent application of cognitive, motor and emotional mechanisms. The joint operation of these mechanisms allows for the system to work properly, on the basis of correct performance of each of the subsystems involved.

(3) One of the central elements in the transactional theory is the fact that information, understood as a relational concept, is the product of the relationship between different subsets of associated elements in a system, which, in turn, possesses certain intentionality, be it cognitive or symbolic. Also relevant to transactional epistemology is the integration of the system's contextual reality into the process of comprehension, as observed with reference to the cultural context.

(4) Apart from the information generated within the system, another decisive aspect must be mentioned when we refer to the possibility of generating knowledge. This aspect alludes to the variability of the signals carrying information in the system, as well as to the variability of the information. The purpose of this epistemological theory is 'to know of and about the external world, not to reproduce its "substance" in the mind' (Buckley 1998). As information is a relational concept, it is impossible to maintain the invariability of the signals carrying information inside the system, on the grounds that information will remain identical in its core, but will present different configurations according to the subsystems in which it is processed.

Consequently, what is really transcendental is not what the image of the real world may be according to our sensory or cognitive 'observations'. Rather, it is the kind of relationship that we engage in with reality and the intentionality with which we develop it that are the basis of how we generate knowledge from reality. From this idea, we infer that this epistemological theory suggests that the objects from which we obtain knowledge are not the tangible objects of reality itself, but the relationships we establish with these objects. Therefore, from an epistemological point of view, this theory transcends the material and formal traditional object of study in order to conceive a relational object with a transactional character. 'Objects are given ontological status, but relations are not, despite the fact that much of science is concerned with establishing such relationships rather than the mere existence of the objects' (Buckley 1998). In relation to this statement, Buckley adds:

> 'If we apply transactionalism to the interactions of objects and events of the external world (leaving aside the role of knower), we may conclude that the properties that define or make knowable such objects or events are always relational and are not totally inherent in the object itself. That is, a property or an attribute of an object refers to the resultant of the interaction of the object with something else, and the something else we select will help establish the property we tend to attach to the object alone. This may apply not only to so-called dispositional properties, but also to those assumed to be inherent. . . . If this is the case, then the presumed object varies in its properties, depending on its relational or systemic context.' (Buckley 1998: 138–139)

When this relational object is an epistemic centre, language begins to play a decisive role to understand the relations between system elements. In this sense, Wittgenstein's *Tractatus logico-philosophicus* argued that language represented the image of the world, but assumed language was isolated from it. According to this principle, mathematics and logic are the instruments of translation with which phenomena are expressed by means of scientific language – an approach adopted by the Circle of Vienna to support their epistemological principles. However, the Second Wittgenstein, departed from his first atomist, strict view and from his theory of language as representation of reality, and in *Philosophical Investigations* he dealt with the game of language, which corresponds to the contextual relational dynamics between objects and reality: 'ontological status might be accorded relations in the external world as well as "objects" and events, especially considering that they all involve some degree of construction in any case' (Buckley 1998).

Reflexive epistemology (second-order cybernetics) (Brunet Icart and Morell Blanch 2001)

Developed by the American mathematician Norbert Wiener, cybernetics is a transdisciplinary science that deals with the study of control and self-control of natural and artificial systems by means of feedback mechanisms (Yolles and Dubois 2001). From an epistemological point of view, this discipline has evolved with reference to the observer's position and role inside the system. First-order cybernetics is founded on the Newtonian mechanist objectivity, and is also known as the 'observed systems' cybernetics. These are predesigned, mechanist systems, controlled by an observer, such as the thermostat and air conditioning systems used for the regulation of temperature. This cybernetics is grounded on feedback mechanisms, understood as recursive processes. According to this conception, its present state is a function of previous states, so that the future state of a system can be prefigured according to its initial configuration. Consequently, the system evolves towards a final goal that will be attained in due time, allowing for no modification.

Second-order cybernetics, developed by Von Foerster and W.R. Ashby refers to 'observer systems'. This conception of cybernetics is related to quantum mechanics and the main difference from first-order cybernetics (Newtonian mechanics) lies in the fact that second-order cybernetics claims that data cannot be obtained objectively, independently from the phenomenon itself. In all cases, an observer experiences the phenomenon and interprets it within the system. Therefore, the existence of that observer inevitably introduces a degree of subjectivity into the data observed. Second-order cybernetics assumes Shannon's ICT, and poses a particular relationship between observer and reality on the basis of the contact-generated information. The basic principle underlying this approach is that the message generated inside the system, or inside the system in relation to the environment, can only be comprehended by the receiver if cultural references are shared with those of the sender. If it does not, the message may even be understood differently from the sender's intentionality, as the message itself is conformed by interpretable data. From this point of view, second-order cybernetics intertwines observer and observed, and the system's initial goal is constantly modified as the system itself evolves into new levels of complexity. Underlying second-order cybernetics we find a reflexive epistemology, which obtains this denomination from its central thesis: 'a world devoid of reflexivity could not have generated any subject, nor would it be intelligible for a subject' (Brunet Icart and Morell Blanch 2001).[1]

With regard to the subject–object relationship, reflexive epistemology argues that subject and object are inextricably united and that their existence is a product of their own relationship. In every system, subject and object are present; the subject objectifies the object, and the object reflects the subjective activity of the subject in relation to the reality in which it is incarnated. It is, therefore, a process of reciprocal objectivation.

> 'Reflection on scientific practice and its tools serves to make explicit the implicit principles of the observer's position, that is to say, to determine the subject's conditions for the possibility of knowledge on the object, as the object is not external and independent from he subject, but the outcome of the subject's objectifying activity. As a result, it is not difficult to grasp what this approach implies: objectivities observed by science are not totally free from intrinsic epistemic limitations. Science deals with objectivities surrounded by intrinsic epistemic limitations, so that those subjectivities are not susceptible of being conceived as absolute, self-sufficient realities, as well as totally independent from the action of the epistemic subject. This is second order cybernetics' highest achievement.'[2] (Brunet Icart and Morell Blanch 2001: 33)

Reflexive epistemology enunciates its main tenet in accordance with that argument: 'the object can only be defined in relation to the subject'[3] (Brunet Icart and Morell Blanch 2001). For that reason, it can be described as an epistemology of the subjective:

'In contrast to classical science, which tries to know objects by expelling their two most common characteristics from reality (subject and values), non-classical science focuses on the actions of subjects, i.e. reincorporates the subject and its values into reality. First-order cybernetics did so in a restricted way, and second-order cybernetics in a generalized mode.'[4] (Brunet Icart and Morell Blanch 2001: 34)

As well as sharing its basic principles with transactional epistemology – its grounding in GST and ICT – both epistemologies show a clear reference to a relational object of study, which transcends the material and/or formal character of the study objects approached by exact and natural sciences, as well as of social and humanistic disciplines. Furthermore, reflexive epistemology exerts a direct critique on the objective character of classical science when faced with a reality in which it distinguishes analysable phenomena. Objectivity is not a property alien to the subject: it is the subject itself who objectifies reality. For that reason, in the 'objectified objects' of reality, no matter what disciplinary approach is taken, there exists a material and/or formal subject and an objectifying subject.

Finally, another point of convergence between the two epistemologies reviewed lies in the inclusion of contexts in the subject–object relation: 'What is relevant in second-order cybernetics is the contexts in which observation takes place, as well as the performance of the systems that monitor the observations of other systems, which grasp and update society from their own particular viewpoints'.[5] (Brunet Icart and Morell Blanch 2001)

Political epistemology (post-normal science – science with people)

Similar to the epistemologies previously reviewed, post-normal science (Funtowicz and Ravetz 2000) emerges as an alternative to the research models of classical science. The main goal of this approach is to face the complexity of contemporary problematic situations with an epistemology of negotiation, not only at the level of disciplinary areas– advocating the intersection of hard sciences (natural) and soft sciences (social) – but also at a social level, promoting the active participation of society in knowledge generation processes. In this context, the classical models' view of the scientist as a neutral observer is to be replaced by an expanded peer community, in which both scientists and individuals affected by the diverse problems share a dialogical relation in case analysis processes and in decision-making processes. This extended cooperation between science and society confers this epistemology a political property that serves to distinguish it from other models.

The denomination 'post-normal science' originates from Kuhn's distinction between 'normal' classical science, which can explain phenomena within their specific area of reality, and 'post-normal' sciences. These new kinds of sciences abandon the explicatory structure of normal sciences, based on a reductionist Cartesian model, and opt for an interactive, dialogical model that integrates spatial and temporal dimensions. In addition, it assumes the dynamic character of reality and the processes that occur within it, as well as assuming the historical dimension of the various challenges.

Finally, this proposal assumes that external features of the study object must be internalized; thus, it is recognition of the transcendence of contexts in conditioning the challenges in society.

'. . . traditional laboratory science must evolve in order to provide answers to the challenges posed at a global scale. The scientific methodology used for dealing with these new issues cannot be the same as that which contributed to create them. A great part of the success of traditional science lies in its ability to be abstracted from uncertainty in knowledge and values; this has been proved in the dominant educational tradition, by creating a universe of unquestionable facts. Nowadays, scientific expertise (the character of being an expert) is unable to provide answers to the political dilemmas to which it has carried humanity by itself. We have not only lost control and predictability, we face a radical uncertainty, and even ignorance, as well as ethical uncertainties that lie within the heart of the scientific policy problems.'[6] (Funtowicz and Ravetz 2000: 28–29)

Contrary to classical science, whose purpose was to enunciate the certainty of phenomena and mastery over nature through knowledge, the challenge for a new science lies in managing uncertainty by means of processes that guarantee an optimum information quality in the phenomena analysed, so that a correct decision can be made. As a consequence, what is proposed is not only the integration of products as generated knowledge on the object of study, but also the participation of the people and the processes involved, so that an extended peer community is conformed, and popular knowledge can intentionally make its way into the scientific domain through the participation of all actors involved; not only in a passive way by means of the application of classical science's scientific validation mechanisms, as in the traditional *modus operandi*.

This model follows the same guidelines of the epistemological models mentioned above as far as the conception of a complex systemic reality and the need to reform scientific practices are concerned. However, it points out two transcendental issues: first, the value of the participation of those involved in the phenomena in order to contribute to the development of a scientific model suitable for their analysis, by recognizing that they represent a dimension of reality that has not been attained by classical science. That dimension is precisely the one that has led to ever increasing uncertainty inside highly transcendent issues for humanity. Second, as a consequence of the previous aspect, a political dimension appears in science, according to which the problems carried under research must be conditioned by two circumstances. On the one hand, in the scientific domain, a problem exists when it is transcendent for the whole of society, in which academic and scientific circles are included; therefore, a problem must be comprehended totally: if it were faced partially, it would be impossible to reflect the relation with society, which is itself an adaptative complex system. On the other hand, knowledge generated on these issues through research processes must allow for decision-making procedures, since the usefulness of knowledge must transcend academic fields, and knowledge does not belong exclusively to them, but rather to the social environment from which they derive.

An epistemological proposal for the science of sustainability

The epistemological proposal for sustainability science presented in this paper has been built upon the above reviewed epistemologies, together with some conceptual approaches, towards an epistemology of sustainability proposed by Gallopin 2001. Similarly, due to the impossibility of constructing an epistemological model without a contextual reference where concepts and their dynamism may be analysed, this approach has been grounded in the health/disease relation, which is a contemporary problematic phenomenon in the general context of sustainable development.

General principles

According to Gallopin (2001), an epistemology for sustainability must emphasize three essential aspects that receive a different treatment from that of classical epistemology. They are the concepts of study object, integration and truth criteria.

Study object

For sustainability science, the study object is no other than the socio-ecological system – Gallopin identifies this system, from a global point of view, as the Earth system. Being a systemic object, it possesses a wide range of dimensions, from the local to the global, and it is integrated by two subsystems: the human and the ecological, which can be further deconstructed, hierarchically, into other subsystems. Furthermore, inter- and intra-system relations are also taken into account.

Interdisciplinarity. Because of its systemic character and the consideration of human and ecological subsystems as study objects, our proposal necessarily implies that the approach to sustainability science is essentially interdisciplinary, and it must be so in order to be able to comprehend its study object. Furthermore, in agreement with Gallopin, both the qualitative and the quantitative dimensions of the object must be analysed.

In concordance with GST, this epistemology for sustainability does not only deal with a simple addition of variables observed in the observed phenomena, but also implies a profounder discrimination of the system components. As Gallopin states, in sustainability's scientific domain there are two aspects related to the 'observation of the whole'. First, the discipline requires identification and comprehension of the system components and the relations established among them; on the grounds that they are the elements that provide identity to the system. Therefore, to recognise them and understand how they are interconnected, is essential in order to establish the way changes occur at the component level, as well as those that affect the actual relations and that also affect the supra-system: following the horizontal axis, 'inter-sector', intra-sector and intra-system relationships can be found. On the other hand, vertical relationships within the system appear on a temporal dimension which is integrated in the system's behaviour analysis. Second, it is necessary to achieve a profound comprehension of the system's dynamics, by investigating how its different components and their interaction generate processes that allow for the correct performance of the system, by means of response generation, emerging properties, and transformations and adaptations inside the system. This diverse emergence of conditions and situations makes it necessary for research to be done from an interdisciplinary point of view.

The truth criterion. It is also necessary to reassess the positivist criterion for the definition of what should be considered as true in science and what should not. At present, the truth criterion has been based on the negation or confirmation of a hypothesis. In our opinion, it is necessary to broaden the principle of caution in sustainability research, and provide it both with an ontological and an epistemological status, because the existence of facts and phenomena that are not comprehensible by means of the positivist model cannot be further denied. In this sense, classical science has proved unable to understand relational factors in real phenomena and the way in which they contribute to phenomenal complexity.

A meta-theoretical model for health based on our proposal for an epistemology of sustainability

From the viewpoint of sustainable development, the health–disease relation is conditioned by the biological elements that identify both elements, as well as by external factors concerning the economic, the social, the psychological, the political and the environmental spheres of reality. It is the sum of these factors that determines the way in which society assumes, perceives and lives through them at a cultural level.

From an epistemology of sustainability, the relation health–disease must be assumed as a relational phenomenon which, rather than being a state, becomes a dynamic process that spans from the individual to the social sphere, and is related to the presence of multiple psycho-physiological states. These are influenced, to a larger or smaller extent, both in their manifestation and in their interpretation, by social, psychological, cultural, political, economic and environmental factors of a temporary kind, and are conditioned by the history of individuals, of the community and by their environment. We must always base our approach on the assumption that there is nothing static in the human being, who is permanently in a continuous evolution of complex processes.

In most recent literature there have been some theoretical proposals that have aimed at reconceptualizing the health area from a more holistic conception. In the area of social studies on health, some of the theories presented are coincident with the proposal made in this paper, being based on a sustainability approach. One of them is McElroy and Jezewski's (2000), based on the phenomenology of health, which connects the individual's experience and their subjectivity to physical variations and external conditioning factors, both at an individual and a social level. According to this theoretical model, an individual's health experience involves three analytic levels of reality: the individual, referring to the individual identity and its bio/ontogenetic aspects; the micro-cultural, involving interpersonal roles and interactions, as well as familiar and group traditions; and the macro-cultural, including cultural and intercultural systems. When disease appears, what the authors denominate the 'disease triangle' also appears: the individual experience intersects the three spheres; the meaning of the disease shows, both individually and collectively, through the relations between multiple systems, and the limits between systems become permeable. Finally, language, understood as a reflection of culture, is essential to define the way in which the disease experience presents a certain symbology, at an individual and a collective level: ' "Communicating through idioms of distress," culturally distinctive ways of symbolizing and imaging illness and injury, symptoms become "grounded in the social and cultural realities of individual patients' " (McElroy and Jezewski 2000: 193).

In the following pages we propose a meta-theory for the health–disease relation based on the principles of the epistemology for sustainability. Our theory takes into consideration the fact that this new science of complexity faces contemporary challenges and reconfigures them in meta-theoretical models in which interrelations transcend material and formal elements.

A meta-theoretical reality

Reality, understood as the whole in which all existing and potential relations are present, can be conceived as a triangle formed by three interconnected axes. Time and space conform two of them, both stemming from the same origin – the Big Bang Theory: the time axis is projected vertically, originating at a zero point, from which the space axis runs horizontally. Both axes create a right angle, whose terminals are closed by a third axis that corresponds to that developed from Gadamer's hermeneutic image of being, which represents not man, but the ontological. The resulting figure represents 'space', in which each edge represents the dimensions of reality and all phenomena are determined (Figure 1). Each of the axes that make up reality is a supra-system. Similarly, all aspects associated to it are interrelated: the spatial axis corresponds to the geophysical supra-system; the temporal axis is the historical supra-system; and the axis of being is the bio-ontological supra-system. These systems do not add up to each other to configure reality. Figure 2 shows, supra-systems are united to each other in order to form the triangular figure. Thus, the whole of reality does not result from the addition of the abovementioned dimensions. As a matter of fact, reality is every one of them and all of them simultaneously (Figure 3)

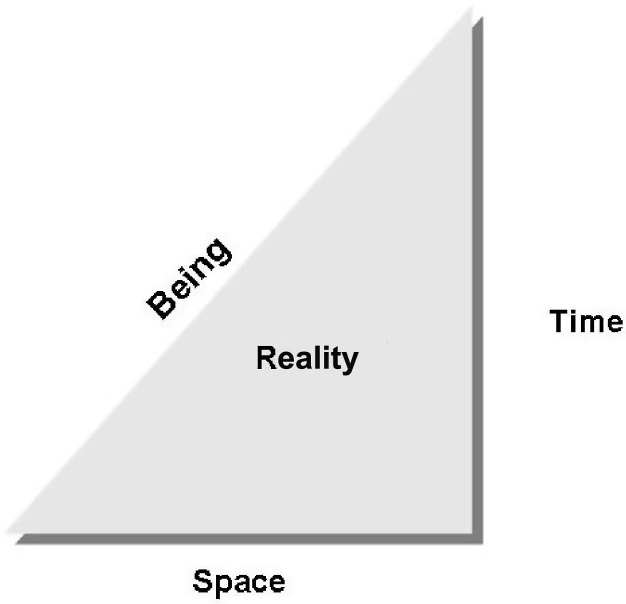

Figure 1. Axes of reality.

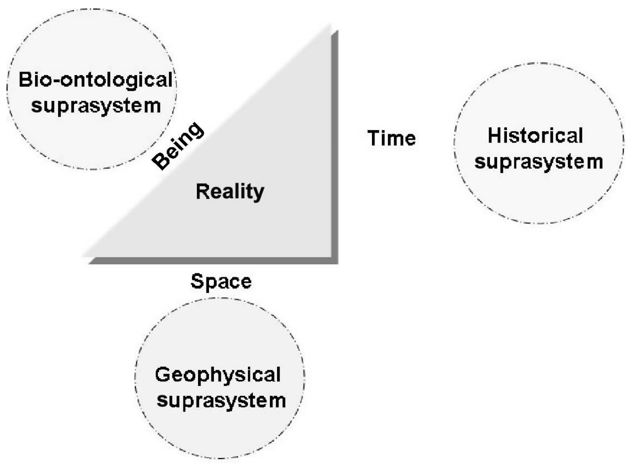

Figure 2. Suprasystems in reality.

The main feature of this model of reality is that it is not static, as reality is dynamic, emerging and self-organized. Being immersed in an ascendant and dynamic movement – a conception based on the Aristotelian approach of 'dynamic being', full of potential, as a perpetual, unfinished action, in perpetual motion, with an inherent *enérgeia* – it is possible to represent it as a spiral, which is similar to the tri-dimensional molecular structure of DNA, discovered by Watson and Crick in 1953, and formed by two chains of nucleotides spiralling around a vertical axis. In the spiral figure representing reality, the time and the space axes are intertwined spirals linked by the axis of existence. The being progresses in time and space, and every event, which is a product of the intersection between time–being–-space, shows the reality of existence (Figure 4).

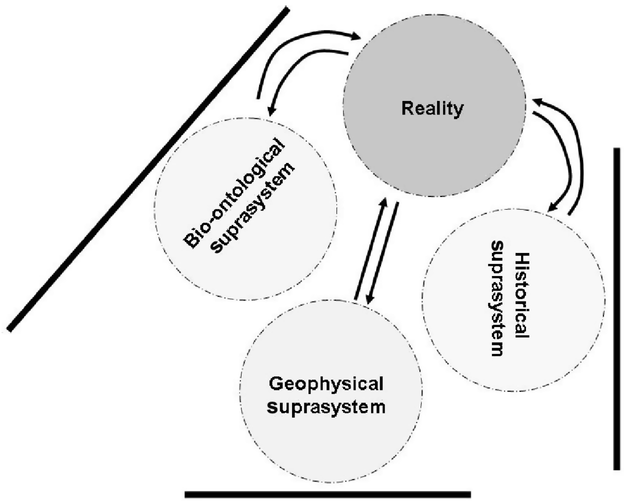

Figure 3. Suprasystemic reality.

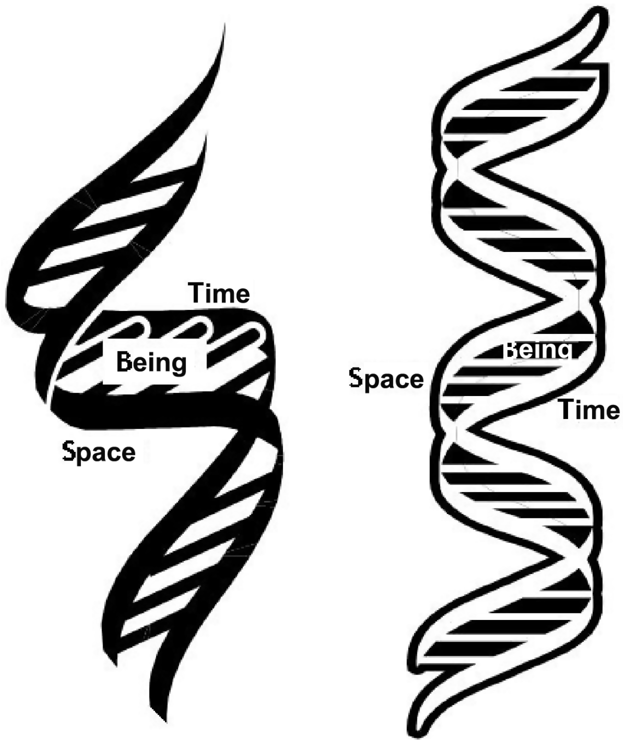

Figure 4. Representation of reality.

Western civilization has adopted a strategy that evaluates lists and catalogues every event of its reality by means of fragmentation procedures. This orientation has led to the instrumentalization of being, as well as to an external use of time and space as tools for contextualizing events from the outside. Following this approach, the scientist faces a complex and incomprehensible reality that does not conform to the reductionist logic of positivist science and its emphasis on the material and static dimensions of being. The metatheory proposed presents the health–disease relation as the intersections between the three dimensions of reality. The boundary of what is considered health and what is disease emerges from the intersection of the three axes. Consequently, the health–disease question is a relational phenomenon in which geophysical (space), historical (time) and bio-ontological (being) dimensions must be taken into consideration in order to achieve a comprehensive understanding of the whole problem.

In the bio-ontological aspect, the quantitative (phenomenological) and the qualitative (positivist) are associated, so that, from this point of view, the health–disease relation can be assumed as a system presenting a similar structure to those in traditional biological systems. Traditional systems, from an organizational viewpoint, are deemed to be closed, but from the informational approach – the basis of the systemic conception – they are configured as open systems.

When the relation health–disease was objectivized as a tangible fact in Western civilization, it was configured as an organizationally closed system, adopting a biomedical viewpoint. Nowadays, it is beginning to be conceived, according to sociological theories on health and sustainability science, as an informationally open system, because of the impossibility of accessing objective truth in a multi-layered phenomenon, in which every dimension shows different but complementary information on the health–disease relation.

Some reflections on the new epistemology for sustainability and its application in health

At an epistemological level, biomedical sciences devoted to the health–disease relation have usually considered its study object as bi-dimensional, the first dimension being material and related to the senses, and the second formal and perceptible. The material component of the study object refers to the factual elements inside the pathological process, i.e. the presence of the etiological agent of an infectious disease, such as *Plasmodium falciparum* in malaria. The formal object is conformed by the contexts in which the material element may be studied, such as the association between a microorganism's genetics and its capacity to produce damage or the physio-pathological alterations suffered by an individual when infected by a microorganism.

Assuming the need to transcend classical epistemological models, new sciences require a study object in which what is scientifically relevant is not the material aspect, nor even the formal, but both of them, as well as the relation established between object – material/formal – and its context, as suggested when referring to migrations affecting the incidence of malaria. This fact, a non-biomedical element of the disease, contextualizes the phenomenon within society and demands reconsidering new emerging elements in the pathological processes, in allusion to issues of ecological, political, social, economic and cultural kinds. For that reason, a study object in sustainability science cannot be configured from the material–formal, but from the relations established among the different dimensions intersecting the phenomena. Thus, the characteristics of a relational study object for sustainability science can be described as having the following properties:

(1) The relational study object has an informational character. Hence, the material and/or the formal aspects in the health–disease phenomenon are transcended by their capacity for generating information on the relations established among the elements.
(2) It is a dynamic study object, as there is no ultimate set of specific relations that may be used to describe a disease: the being axis, a part of reality, is conformed by social, cultural, political and economic dimensions, among others, which condition the presence of a pathological event. As a result, the biological characteristics of disease, which were the study object of positivist science, must be reformulated and conceived as an element of a systemic relation that interacts with other factors of reality, which are, in turn, associated to the pathological event. Thanks to this feature, the relational study object is constructed and reconstructed constantly according to information exchanges between the different subsystems conforming to the pathological phenomenon.
(3) From a systemic point of view, the study object is bi-dimensional. If we assume the systemic composition of the bio-ontological dimension, we find that the study object possesses an internal dimension, related to the individual and including biological traits, as well as an external dimension, which refers to the social dimension of the phenomenon.
(4) The study object shows a collaborative character, because it is constructed by the members of the community and the institutions participating in the pathological phenomenon.
(5) The study object is intentional, as the goal of comprehending the object is not to represent it as an isolated, static object, as it may apparently appear, but to approach the object dynamically, including its interactions with other phenomena existing in the reality in which the object itself exists. Thus, it can be comprehended and can even be acted upon.
(6) The study object is trans-disciplinary, as it involves different dimensions that transgress the boundaries of just one discipline. Therefore, the disciplines involved in the consolidation of the study object must set off to establish the existing relationships between the different disciplinary standpoints, so that a new trans-disciplinary attitude toward the object can be found.
(7) The study object is dialogical, as its consolidation, analysis, transformation and reconstruction requires ongoing negotiation activities that can only be carried out through language.
(8) Finally, space and time recreate the different scenarios in which the health–disease relation is found. The double helix graph representing the meta-theoretical model proposed (Figure 4) generates a different scenario in each intersection, which is to be understood as a different health state. The stability of each element of the pathological system is only relevant when in interaction with the other elements. In every new state of the phenomenon, the components of the system are reconfigured, whereas new ones arise and others disappear. All these processes lead to variations in the presentation of the phenomenon.

The main difference from the positivist approach is that this aims exclusively at comprehending the elements, in an increasingly more specific way. Besides, by adding data, it also tries to process them and analyse them in order to achieve a satisfactory description of the phenomenon (which is understood as the sum of the parts analysed). In contrast, the epistemology for sustainability proposed in this paper assumes that a phenomenon is not the sum of its parts, but the relation between them. Thus, it needs to know the parts, but also requires an overview of the phenomenon as a whole.

Discussion

The classical conception of sustainable development conceives the problematic reality as configured by four dimensions: the social, the economic, the environmental and the institutional. These four dimensions are interrelated and define diverse and varying situations, in which contemporary challenges for humanity are found. From that point of view, the epistemological proposals reviewed here are compatible with a systemic conception of reality. Sustainability, from the disciplinary domain, transcends the relation subject–object of classical science and poses a relational element as study object, in which the spatiotemporal dimension and the contexts for those relations are included. In this sense, science shows an increasing awareness of the emergence of ever-increasing complex challenges in the contemporary world – towards which classical science is growingly perceived as incapable of dealing with and providing effective answers. This situation has led to the appearance of GST; the *helicon* of the epistemological proposals reviewed, and has allowed for later derivations at an epistemological level. These derived epistemologies have developed into the epistemological models that have proved most suitable for analysis of the contemporary challenges. However, it is necessary to clarify some relevant aspects of the proposed epistemology, such as overcoming the positivist approach, the conception of sustainability as a discipline, and the methodological concretion of the new epistemological models.

First, the positivist epistemological model is not obliterated by the new epistemologies, because it has exceedingly proved its efficiency. Its degree of analysis of reality is a first, and necessary, step in the process of comprehending the wholeness in which data generated by one of the dimensions of reality are inscribed. What have been transformed are the use of different methods and the timing of these methods, as well as the interrelation of the information generated by the application of analytical methods to the phenomenon at issue. For that reason, the positivist model is not erased from the epistemological reality. Instead, it is transcended in order to allow for greater complexity, and is included in the procedures of the new systemic models, from which a new way of understanding reality is proposed. What the new epistemologies suggest, therefore, is a new way of seeing and perceiving.

As for the character of sustainable development as an emerging discipline, it can be argued that the epistemology for sustainability fits perfectly into the problematic character of the systemic, complex reality that allowed for the very emergence of sustainable development. Nevertheless, there is an urgent need for profound discussion on basic aspects, which deal with the necessity of configuring a new discipline of the systemic or a discipline of the sustainable (sustainable development–sustainability), following the guidelines of a unique epistemological model, with a trans-disciplinary character. The alternative to this would be to maintain the unidisciplinary epistemological models of traditional scientific research.

Finally, an issue that needs special attention from researchers is the methodological concretion of the new epistemological proposals. To bring forward a new way of approaching reality is a step towards the conception of the holistic, which is closer to the reality of the phenomena. However, it is necessary to specify the emerging epistemological conceptions into new methodologies referred to environmental, economic, social and cultural problems, as well as the relations taking place between them.

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Notes

1. 'un mundo exento de reflexividad ni podría haber generado sujeto alguno, ni sería inteligible para ningún sujeto.' The translation to English is ours.
2. 'El retorno reflexivo sobre la práctica científica y sus instrumentos responde al fin de explicitar los presupuestos implícitos de la posición del observador, esto es, a determinar las condiciones de posibilidad del conocimiento del objeto por el sujeto, al ser el objeto no algo exterior e independiente del sujeto, sino producto de la actividad objetivadora del sujeto. En consecuencia, no es difícil de ver lo que implica este enfoque: las objetividades contempladas por la ciencia no están libres de limitaciones epistémicas intrínsecas. La ciencia trata con objetividades cercadas por limitaciones epistémicas intrínsecas, por lo que aquéllas objetividades no son susceptibles de ser concebidas como realidades absolutas, autosuficientes y completamente independientes de la acción del sujeto epistémico. Éste es el logro de la cibernética de segundo orden.' The translation to English is ours.
3. 'el objeto sólo es definible en relación con el sujeto.' Idem.
4. 'Frente a la ciencia clásica que trata de conocer los objetos expulsando de la realidad sus dos entidades más características (el sujeto y los valores), la ciencia no clásica centra su atención en las acciones de los sujetos, esto es, reincorpora a la realidad el sujeto y los valores; de manera que la primera cibernética lo efectuó de forma restringida y la segunda cibernética, de modo generalizado.' The translation to English is ours.
5. 'Lo que cuenta en la cibernética de segundo orden son los contextos en los que tiene lugar la observación y la actuación de los sistemas que observan las observaciones de otros sistemas, que observan y actualizan la sociedad desde sus respectivos ángulos concretos.' The translation to English is ours.
6. 'la ciencia de laboratorio tradicional debe evolucionar en respuesta a los desafíos que plantean los riesgos que están acaeciendo en una escala global. La metodología científica para abarcar estos nuevos problemas no puede ser la misma que ayudó a crearlos. Gran parte del éxito de la ciencia tradicional yace en su poder para abstraerse de la incertidumbre en el conocimiento y los valores; se ha mostrado en la tradición educativa dominante, creando un universo de hechos incuestionables. En la actualidad la expertise (el carácter de experto) científica es incapaz de resolver por sí sola los dilemas políticos a que nos ha llevado. No sólo hemos perdido control y predictibilidad; enfrentamos una incertidumbre radical e incluso ignorancia, así como incertidumbres de carácter ético que yacen en el corazón mismo de los problemas de política científica'. The translation is ours.

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