

Dimensions of Systems Thinking

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Abstract

This paper defines systems thinking and contextualizes it in a historical scientific framework. Systems thinking, systems science and systems inquiry are differentiated and the major critiques to systems thinking are presented. The paper concludes with a reflection on the ethical implications of systems thinking for contemporary societies.

Keywords: systems thinking, systems science, systems inquiry, ethics.

What is a System?

A system is a set of interconnected elements which form a whole and show properties which are properties of the whole rather than of the individual elements. This definition is valid for a cell, a society, or a galaxy. Therefore, as Macy (1991) express it, a system is less a thing than a pattern. It consists of a dynamic flow of interactions which is non-summative, irreducible, and integrated at a new level of organization permitted by the interdependence of its parts. The word “system” derives from the Greek “synhistanai” which means “to place together” (Capra, 1996, 27).

To better understand the concept of system, it is useful to differentiate it from the concept of set (Minati, 1996). A set is a collection of non-interactive elements. The characteristics of the set are equal to the characteristics of its elements (see figure 1).

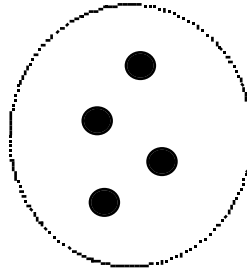


Fig. 1. Set

A structured set is a collection of objects or elements with a some kind of order. In other words, there is some kind of relation between the elements of the set. The characteristics of one element can be deduced by the characteristics of other element within the set and the relationships among them contribute in the explanation of the characteristics of the set. These relationships are indicated by the dotted lines among elements in figure 2.

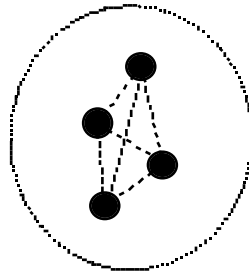


Fig. 2. Structured Set

A system can be defined as a structured set which elements interact among themselves and that has characteristics of the whole no present in the characteristics of its elements or they relationships. A system has an identity beyond that of its elements. It has a throughput of information and energy with its environment that gets transformed from input to output. (See figure 3.) The difference between a set and a system is the level of organization and the complexity of this organization.

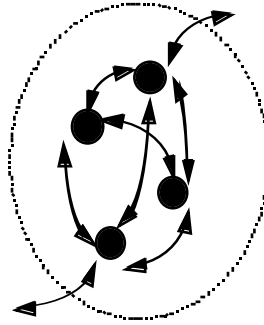


Fig. 3. System

Characteristics and Processes of Systems

A system can be more or less open. The degree of energy and information exchange varies according to the degree of openness of the system. Completely closed systems do not exist in the real world. A machine is a relatively closed system that tends to run down easily, while a living organism is an open system that imports energy from its environment and build in complexity. Through the communication with its environment, an open system both maintains its identity and evolves. That is, on the one hand, the system is homeostatic since it maintains the pattern of its structure. On the other, it self-organizes into higher levels of complexity and order, and in the process its structure is changed.

The integrated processes of homeostasis and self-organization are characteristic of open systems far from thermodynamic equilibrium—systems that prove not to work under the second law of thermodynamics—but that can evolve. The concepts of negative and positive feedback respectively explain these two processes that sustain and create order. Feedback is an output that becomes an input through which the system learns about its own performance. Through negative feedback loops, the system receives information about deviations in its behavior according to the pre-established goals and reduce these deviations. Through positive feedback loops, the system is informed that the pre-established goals are not relevant anymore in the context of its environment, and the system increases the deviation from the goals producing instability and novelty until it arrives to a new level of organized complexity and dynamic stability.

Systems enclose and are enclosed by other systems. This constitutes a natural hierarchy. At higher levels, complexity increases through new levels of differentiation of the parts and their integration and coordination into a coherent whole. The different levels of the hierarchy are in constant communication through exchange of matter, energy and information of the system with its environment. Systems hierarchies are not of rank and authority, but levels of higher or more inclusive integrity that emerge from the interplay of the components. The organizing trust is from the bottom up (Macy, 1991, p. 77).

The systems at higher levels in the natural hierarchy of organized complexity in the universe are less in quantity and more in diversity (Macy, 1991). For example, there are less number of organs in an animal than cells forming these organs, and the organs are more differentiated (they have specialized structures and functions) than the cells. According to this, Laszlo (1972) proposes a systems taxonomy that includes suborganic, organic, and supraorganic levels as modes of organization rather than essence or substance, as it would be a classification such as inorganic, organic, and social systems. From a different point of view, Checkland presents a typology of systems that includes natural systems, designed physical systems, designed abstract systems, and human activity systems, which can also be purposefully designed (Banathy, 1996).

The Development of Systems Thinking

Systems ideas are not new. Heraclitus had the conception that “everything flows,” that is, the process orientation fully embraced by systems thinking. Churchman identifies the *I Ching* as the oldest systems approach (Hammond, 1997, p. 12). Nevertheless, it was in this century when the systems ideas were formalized within scientific thought.

Between 1913 and 1917 Alexander Bogdanov—a Russian medical researcher, economist, and philosopher—published his work on “tektology:” the “science of structures... (that) embraces the subject matter of all other matters” (in Capra, 1996, p. 44). Apparently, “tektology was the first attempt in the history of science to arrive at a systematic formulation of the principles of organization operating in living and nonliving systems.... A universal science of organization” (Capra, 1996, p. 44).

Nevertheless, there are no references of Bogdanov work in the literature of systems thinking.

The systems paradigm—as a coherent framework of thought—came into existence when in the 1920s a handful of scientist from different fields became aware of the potential to develop a general theory of organized complexity (Laszlo, 1975). Systems thinking has biological and technical origins. On the one hand it was pioneered by organismic biologists, and enriched by Gestalt psychologists and ecologists (Capra, 1996, pp. 17-18). On the other, developments in engineering, management, cybernetics, and information theory contributed greatly to the consolidation of systems thinking (Hammond, 1997). Contemporary systems thinking includes a diverse array of perspectives developed since then.

In the Germany of the 1920s, organismic biology and Gestalt psychology were part of a larger cultural movement “against the increasing fragmentation and alienation of human nature.... There was a hunger for wholeness” (Capra, 1996, p. 32). The philosopher Christian von Ehrenfels was the first in use the word Gestalt (i.e., organic form) to indicate that “the whole is more than the sum of its parts” which would become a key maxim of systems thinking later on (Capra, 1996, p. 31). It was the organismic biologist Ludwig von Bertalanffy who formulated the fullest expression of the emerging systems ideas in a General System Theory (GST). His main contribution was the concept of open system (Hammond, 1997, p. 21) and it was his work “that established systems thinking as a major scientific movement” (Capra, 1996, p. 46). Bertalanffy introduced the concept of GST in 1937 (Hammond, 1997, p. 2), however, his first publication on the subject appeared only after World War II. In 1954 Bertalanffy together with Ralph Gerard, Anatol Rapoport, James Miller, and Kenneth Boulding, established the Society for the Advancement of General Systems Theory—what today is the International Society of Systems Sciences.

Norbert Wiener developed cybernetics (from Greek “kybernetes” which means “steersman”) as the science of control and communication in the animal and the machine” (Capra, 1996, p. 51). The cybernetics movement began during the World War II when a group of mathematicians, neuroscientists, engineers, and social scientists began to study the “patterns of communication, especially... closed loops and networks” (Capra, 1996, p. 51). Their research lead to the concepts of feedback, self-

regulation, and later, self-organization. These patterns of organization that were implicit in organismic biology and Gestalt psychology became the explicit focus of cybernetics. The cybernetists set themselves “the challenge of discovering the neural mechanisms underlying mental phenomena and expressing them in explicit mathematical language.... To create an exact science of mind” (p. 52).

In 1946 at the first Macy Conference in New York (the series of conferences where the cybernetic framework was developed and from where the American Society for Cybernetics emerged), two groups that followed distinct lines of inquiry were formed: the mathematicians, engineers, and neuroscientists, such as Wiener and Neumann, on the one hand, and the social scientist and humanists such as Gregory Bateson and Margaret Mead, on the other. The technical research of cybernetics was funded by the military (Capra, 1996, pp. 52-53). The militaristic and technocratic applications of systems ideas within the cybernetic framework have been the main focus of the critiques of the systems approach. The individuals within the general systems society were disturbed with these applications. They did not support them, and in fact, were concerned with developing conceptions of interdependent, participatory, and democratic forms of social organization and with the promotion of diverse perspectives (Hammond, 1997, pp. 4-5). General systems approaches are evolutionary and developmental, emphasize learning and flexibility. Cybernetics emphasizes equilibrium models (Hammond, 1997, p. 16).

Capra (1996) clearly distinguishes between general systems theory and cybernetics. For him, these are two separate strands that weave what we now know as systems thinking. For Laszlo (1975), cybernetics is a “special systems theory” like the mathematical systems theory of Rapoport, the social systems theory of Parsons, or the management and organization systems theory of Churchman, among other interconnected developments. GST, according to him, includes these special systems theories. Hammond (1997, p. 5) sees systems thinkers such as Gregory Bateson, Fritjof Capra, Joanna Macy, James Lovelock, and Hazel Henderson as part of the cultural movement against the totalizing and technocratic conception of systems (or rather, of “the system”) that embrace a more ecological (i.e., deep ecology) orientation. In a continuum of different systems perspectives where one extreme is the technocratic and the other is the ecological, Hammond perceives the founders of the general systems

movement in the middle. These are some of the interpretations of the historical events within the development of systems science. The contemporary understanding of systems thinking includes the concepts developed by both GST and cybernetics, has a strong ecosystemic orientation, and is in continuous expansion, incorporating notions from the new sciences of complexity (e.g., dynamical system theory, autopoietical system theory, catastrophe and chaos theory, nonequilibrium thermodynamics) such as the new understanding of general evolution.

The Relevance of General System Theory

GST promised to provide the ability to draw on emerging parallelisms in different scientific disciplines in order to provide the basis for an integrative science. The analytical method of traditional science gets detailed knowledge of specific and short-term objects and subjects of study, without considering the context and the interconnections between events. As a result, the “knowledge of the environment is segmented into academic compartments, but the environmental factors themselves form an interdependent continuum” (Laszlo, 1975, p. 12). GST tries to identify similarities between biology, anthropology, ecology, sociology, psychology, management, cybernetics, etc., and thereby, advance the societal application of the integrated scientific knowledge.

GST could point out similarities between the theoretical constructions of different disciplines, reveal gaps in empirical knowledge, and provide a language by which experts in different specialties could communicate with each other (Checkland, 1993, p. 103). GST “aims to provide a framework or structure of systems on which to hang the flesh and blood of particular disciplines and particular subject matters in an orderly and coherent corpus of knowledge (Boulding, 1956/1991, p. 248). General systems theorists acknowledge that specialized knowledge is as important as an integrative framework (Hammond, 1997, p. 3).

GST is a general theory of systems, and not a theory of general systems. GST does not seek to establish a single self-contained general theory of practically everything since such theory would be almost without content. GST tries to go beyond the specific theories that have no meaning, to a level of optimum degree of generality

(Boulding, 1956/1991) which will be knowledge relevant to any discipline concerned with real world problems. However, GST has not been fully developed and what we know as GST are only the foundations for a comprehensive theory. As Checkland (1993, p. 94) points out, progress in systems science seems more likely to come from the use and application of the systems ideas in real-world situations, rather than from the development of the overarching theory.

Systems Science, Systems Thinking, and Systems Inquiry

In the systems paradigm, instead of substances the focus is on organization; instead of simple and basic components the focus is on complex units that form a whole; instead of aggregates forming objects the focus is on systems embedded in other systems and composed by other systems (Morin, 1977). Thus, scientific inquiry is changing its attention from components and substance to functions and organization, that is, from elements to systems.

Systems sciences is the encompassing concept that includes a great diversity of areas of study, theories, methodologies, and approaches which seek to connect knowledge across disciplines and understand complexity. The systems sciences include the sciences of complexity—such as dynamical system theory, cybernetics, autopoietical system theory, catastrophe and chaos theory, information and communication theory, and nonequilibrium thermodynamics (Laszlo, 1996, p. 2)—as well as the social systems sciences such as management sciences, emancipatory systems theory, and social systems design.

Kramer and Smit (in Hammond, 1997, p. 19) indicate that there is “no generally accepted, clearly defined body of knowledge concerning systems thinking.” The multiplicity of systems approaches is reflected in the diversity of terms (e.g., systems thinking, systems analysis, systems engineering, systems theory, etc.) some times with overlapping meanings, some times with completely different meanings, and still in most of the cases used indiscriminately (p. 19). Additionally to the employment of the term systems sciences which makes reference to the diverse and interconnected areas of systems studies, there are other terms that make reference to the whole of the

transdisciplinary systems movement such as systems thinking and systems inquiry. The questions is, do they refer to the same thing?

Systems Thinking

Systems thinking is thinking about the world outside ourselves and doing so by the use of the concept “system” (Checkland, 1993, p.3). In other words, it involves cognition in terms of processes, relationships, embeddedness, and interconnections.

Systems thinking is the cognitive process that uses both analysis and synthesis to obtain a comprehensive understanding of a whole in its context. Systems thinking tries to understand the whole (system) and its parts (subsystems), the relations between the parts and the whole, and the relation of the whole with its context or environment (suprasystem). Systems thinking makes emphasis in the understanding of the whole, while the reductionistic approach is interested in the isolated parts. However, it is different than holism since holistic thinking can be reductionistic when it simplifies at the level of the whole instead of at the level of elementary components. Systems thinking transcends both reductionism and holism.

Reductionistic thinking is based on analysis, while systems thinking is based on synthesis additionally to analysis. This is reflected in the definitions of analysis and synthesis provided by the American Heritage Dictionary (1993). Analysis is “the separation of an intellectual or substantial whole into its constituent parts for individual study” while synthesis is “the combining of separate elements or substances to form a coherent whole.” Systems thinking, through both analysis and synthesis at different levels of integration, is an expression of expansionism that looks for emergence and creativity.

On the one hand, reductionistic thinking (as used in the standard view of science) applies the processes of induction and deduction (Polkinghorn, 1983, p. 100); it tries “to provide explanations for the new unknown, in terms of the known” (Checkland, 1993, p. 64). On the other hand, systems thinking applies induction, deduction, *and* abduction (Banathy, 1996, p. 34); it involves creativity and generation of new knowledge from what is already known. Pierce called “abduction” to “a kind of inference to explanatory hypothesis” (Holland, et. al., 1989, p. 89) which “involves the generalization of

hypothesis in order to find potential explanations of puzzling phenomena. Explanation can be thought of as a kind of problem solving” (p. 136). In this case, the motive to generalize is not to summarize knowledge about specific cases, but to produce new ideas to be further explored.

Systems thinking implies the understanding of the complementariness and unity of “apparent opposites” and of the interactions that join them, instead of focusing on the competitive characteristics that exist between them (Morin, 1992, p. 373). Something is complex because it forces us to integrate ideas that seem mutually exclusive within the framework of reductionistic thinking (Morin, 1992, p. 381). Therefore, apparent opposites—such as men and women, east and west, self and other, mind and body, reason and emotion, science and spirituality, work and play, life and learning, society and ecosystem—are interdependent complements that should coexist in harmonious balance and unity.

In short, systems thinking is a cognitive process that involves:

- thinking about the world using the concept of system—in terms of processes, connectedness, and relationships rather than isolated elements;
- analysis and synthesis at the different systems levels always taking into account the context;
- induction, deduction, and abduction; and
- transcending “apparent opposites.”

Systems Inquiry

Systems inquiry is the disciplined action-research that uses systems thinking to understand, improve, and/or emancipate the world. “Systems inquiry has demonstrated its capability in dealing effectively with highly complex and large-scale problem situations. It has orchestrated the efforts of various disciplines within the framework of systems thinking. It has introduced systems approaches and methods to the analysis, design, development, evaluation, and management of systems of all kinds” (Banathy, 1991, p. 31).

Systems inquiry is the integration of systems philosophy, systems theory, and systems methodology to create transdisciplinary knowledge and address complex real

world situations (Banathy, 1992). These three components make of systems inquiry a comprehensive and robust intellectual system.

Systems philosophy sets forth a reorganization of ways of perceiving and thinking. “It creates a new worldview, a new paradigm of perception and explanation, which is manifested in integration, holistic thinking, purpose-seeking, mutual causality, and process-focused inquiry” (Banathy, 1991, p. 32). Systems thinking is systems philosophy as a process; thus, systems inquiry is a more comprehensive knowledge generating system that includes systems thinking and theoretical and practical knowledge.

Systems theory “pursues the scientific exploration and understanding of systems that exist in the various realms of experience, in order to arrive at a general theory of systems: an organized expressing of sets of interrelated concepts and principles that apply to all systems” (Banathy, 1991, p. 31). For instance, General System Theory (GST), which main interest is on systems per se, is a formalized and holistic body of knowledge “which aspire to embrace different sciences by discovering concepts, laws, and models applicable to systems of all types” (Lane & Jackson, 1995, p. 219). There are also specific systems theories that focuses in concrete areas of study. That is the case of the work of Parsons in sociology, Churchman and Ackoff in management, and Vickers in human communication (Laszlo, 1975). These specific systems theories have contributed to the understanding of systems across the disciplines.

Through the application of systems theory and systems philosophy, systems methodology “has developed approaches, strategies, and methods of analysis, design, and development in the context of complex systems. It has also developed approaches to and methods for the management and change of systems, and the management of problem situations” (Banathy, 1991, p. 32).

Systems inquiry represents a consolidating and integrating tendency in the systems area. Systems inquiry is applicable in many different disciplines, and this is what Checkland and others call “the systems movement”—the attempts in all areas of study to think and conduct action-research in a systemic rather than in a reductionistic way.

Critiques to Systems Thinking

The transdisciplinary nature of systems thinking provokes indifference or fear in those that find it conflictual or challenging to their analytical way of thinking. The critiques of systems thinking are most of the cases based on misconceptions or generalizations of what systems thinking is.

Aside from its solid foundations, “the GST envisaged by the founders has certainly not emerged” (Checkland, 1993, p.93). As a result, Naughton (in Checkland, 1993, p. 93) suggests that there is “nothing approaching a coherent body of tested knowledge to attack, rather ‘a mélange of insights, theorems, tautologies and hunches’....” Hoose (1983) criticizes GST because it is “too general in focus and vague in scope to constitute a theoretical framework and is too eclectic to merit consideration as a discipline” (p. 78).

In many cases, “systems thinking has come to be associated with the highly rationalized technological and institutional systems of the late twentieth century, and the concept of system has become synonymous with control and totalization” (Hammond, 1997, p. 4). For instance, Thompson (1976) thinks that systems concepts can be used to control the academic disciplines and social institutions and to monopolize knowledge and promote the elite of systems intellectuals.

Another confusion is to consider systems thinking as equivalent to cybernetics. The fear of those who criticize the systems movement under this confusion, such as Berman (1986), is that systems approaches conceive the world as a computer, which is as mechanical and reductionistic as the model of the clockwork under the Newtonian paradigm. GST was a replacement for reductionism while cybernetics was an extension of the mechanistic model (Hammond, 1997, p. 67). Additionally, the militaristic and technocratic applications of systems ideas within the cybernetic framework have been the main focus of the critiques of the systems approach in general (Hammond, 1997, p. 4). Unfortunately, some times systems thinking as a whole is incorrectly portrayed as have emerged from military initiatives (e.g., Collen, 1995, p. 45). It is cybernetics, and not general systems theory and its developments, that at one point was linked to military research.

“Most critiques of systems theory tend to treat the development of systems thinking as an integrated and coherent phenomenon and to downplay the considerable diversity in the perspectives and ideological orientations of different approaches to understanding systems” (Hammond, 1997, p. 4). On the one hand, the systems view tends to be considered the apotheosis of modernity—positivistic, technocratic, and rationalistic. On the other, it reflects facets of the postmodern perspective in its concern with pluralism and social construction (Hammond, 1997, p. 28). Systems thinking is so diverse that generalized critiques that attack one aspect without considering the different and complementary perspectives within systems science are inappropriate and misleading.

Implications of Systems Inquiry for Today and Tomorrow

Our age, turbulent and unstable, is marked by the interrelated complex of world problems. As C.H. Waddington notes: “We have found ourselves faced by a series of problems—atomic warfare, the population explosion, the food problem, energy, natural resources, pollution and so on—each complex enough in itself, but then it turns out that each of these is only one aspect of, as it were a Total Problem, in which all aspects of the world’s workings are inter-related” (in Merry, 1995, p. 78). These problems are the consequences of our reductionistic ways of living and interacting. “This is a crisis of intellectual, moral, and spiritual dimensions of a scale and urgency unprecedented in human history” (Merry, 1995, p. 94). It is our challenge and responsibility to create the pathways to an ethical future.

The progress of science and technology have affected our lives in many positive ways. However, the progress that we have experienced has had some side-effects—effects which we had not foreseen or do not want to think about (Meadows, 1972)—that are threatening life on this planet. There is a big gap between our ability to create new technologies and our ability to create harmonious socio-cultural systems (Banathy, 1991). We have been focused on the “know-how” questions to foster growth and progress, but we have neglected the “know-why” questions to understand the consequences of our actions. As a result, our technical knowledge is lacking the humanistic wisdom necessary to have a sustainable, or ethical in a human and

ecological sense, development. It seems like we have hardly begun to ask the “what should be” questions that could guide us to create an ethical future and to become stewards of our evolution.

Today, the world works within a value system of expansion, competition, domination, and exploitation that we, collectively, accept and promote. What is keeping us from embracing the values of harmony, cooperation, partnership, and respect? It is the inner limits of humankind, our outmoded ways of thinking, the bounds of our will and understanding, that obstruct our evolution towards a better future (Laszlo, 1989, p. 14). Einstein and Russell acknowledged that “we have to learn to think in a new way” (1957). The possibilities for an ethical future depend on our ability to think in a new way. “Without a new thinking to replace traditional dichotomous modes of cognition and motivation, and without practical means to resolve perceived and real differences of interests between nations and peoples” any proposal to transcend our problems is “likely to fall upon the deaf ears of those who believe they have nothing to gain, and their self-images, wealth, and power to lose, from such a ‘revolution’” (Webel, 1996, p. 20).

Chaisson (1987) believes that “we must make synonymous the words ‘future’ and ‘ethical,’ thus terming our next grand evolutionary epoch ‘ethical evolution’” (p. 201). Singer (1995) defines (practical) ethics as to think, live, and act according to a broader perspective of the world and beyond one’s own interests (p. 174-175). Many of the current individual and collective practices (e.g., business practices) are unethical according to this definition since they are focused on egocentric and short-term interests. But how broader should be the perspective of the world, and how far beyond ourselves should our thoughts and actions be in order to be ethical? To evolve with distinction, rather than devolve to extinction, we need to learn systems thinking.

“We have to find an appropriate moral code to guide our choices. It should be a code that takes into account the wisdom of tradition, yet is inspired by the future rather than the past; it should specify right as being the unfolding of the maximum individual potential joined with the achievement of the greatest social and environmental harmony. The development of this code is no easy task...” (Csikszentmihalyi, 1993, p. 162). Jantsch (1980) believed that the task is to create a multilevel ethics that integrates individual and whole systems ethics with the general ethics of overall evolution (p. 17).

The development of an evolutionary ethic requires a systemic understanding of our place in the world and the ability to use systems thinking in all aspects of our life. If we manage to transcend our reductionistic and myopic assumptions about ourselves and the world, there will be hope for humanity and planet Earth, and a new age of unlimited possibilities will emerge.

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