An Introduction to the Nature of Wicked Problems Ecological Challenges as Super Wicked Problems

BITTENCOURT, E.

Universidade Estadual de Campinas, Campinas

Corresponding author, e_bittencourt@uol.com.br

Abstract

In this paper the concept of "wickedness" is discussed, considering its importance to correctly deal with problems emerging in ecological systems. The term "wicked problem" was coined by Horst Rittel, who with colleagues perceived the failure of linear approaches to treat design and planning. Failing to recognize a problem as "wicked", results in the utilization of inappropriate tools to solve problems in climate change, leading to the use of inadequate methodology and management procedures, restricted to treat "tame problems". Ecological issues are considered as "super-wicked" problems, due to its innumerous uncertainties, interdependencies, complexity, and social fragmentation introduced by the stakeholders involved. Ecological systems consist of an integrated and coherent association of dissipative structures, where the whole is not the result of the simple sum of its parts, as well known from complexity theory. Ecology consists of a network of open, nonlinear systems, hierarchically structured, forming a highly integrated, adaptative whole of the living and non-living, entangled with social, cultural, and economic phenomena. How we perceive and manage this complex network will affect the future of our planet, and hopefully, correctly orient the decisions on ecological issues, as well as contribute to the effort to implement cleaner production practices. We strongly emphasize that this group of problems –wicked- should be made more familiar to students, early in their careers.

Keywords: *wicked, complexity, ecology, cleaner production*

1. Introduction

In "Systems, Messes and Interactive planning", Russell Ackoff, refers to the "Machine Age Thinking", as "analytical and based on the doctrines of *reductionism and mechanism*". According to theories dominating the scientific world in the last century, the whole could be analyzed by dissecting the system to its ultimate elements. "Every science sought its ultimate elements"(Ackoff, 2013). Complex problems were cut down to smaller, simpler problems. As an example, it was believed that the problem of running a city could be broken down into "running transportation, housing, health, education and so on".

The *cause-effect* principle establishes that the *cause* is both necessary and sufficient to determine the *effect* – determinism prevailed then. Everything that occurred at a certain time was the result of something that preceded it. If the *effect* is undesirable, eliminating the *cause* would solve the problem.

The Universe was seen as a machine, excluding emergence, free will, purpose, choice, and chance. Ackoff classify some systems as *non environmental*– such as vacuum systems and laboratories, understood as typically closed systems, and necessary for observations and measurements. However, it is clear to our objectives the limitations of closed systems, and evident the importance of problems that are not environment-*free.* Systems of our interest in this paper are contrarily, open, environment-bound systems, which cannot be closed to be analyzed - its *openness* is an essential part of its nature and phenomenology. By necessity, they have to be investigated and understood as open systems, interacting with the environment. Furthermore, ecological and economic problems, due to its very high complexity, consist in "super-wicked problems". All sciences are necessary to the ecological science, a science of very high complexity, demanding an interdisciplinary approach.

In the paper "From Modern Thermodynamics to How Nature Works – a View of Emergent Paradigms Associated with Sustainability", Bittencourt (2011) discusses the role of irreversible, non-linear thermodynamics, in understanding and dealing with environment-bound systems, establishing a scientific basis for the study of ecological problems, which encompass social, cultural, and economic issues. Systems of key interest to the issue of sustainability are open, coherent, purposive, and irreversible.

The fascinating evolution in the last 50 years in science led to the study of ecological systems as a complex (super-wicked, super-complex) integrated whole. This view is clearly expressed in the title of the work of James Kay (2000), "Ecosystems as Self-Organizing Holarchic Opens Systems: Narratives and the Second Law of Thermodynamics". James Kay coined the term "SOHO" (Self Organizing, Holarchic, Open Systems), to describe ecological systems. Bittencourt (1999) also ended up with four letters to describe those systems: "OCPI" - meaning systems which are Open, Coherent, Purposive, and Irreversible. Irreversibility is at the core of energy consumption and pollution challenges, since all living beings, as well as all productive structures built and operated by man, constitute a collection of dissipative structures, which consumes negative entropy and discharges positive entropy in the environment. The implementation of cleaner production techniques is a tool to reduce the damage of human made dissipative structures, thus contributing to the quality of the life in the planet. "Eco-friendly" processes minimize (but do not eliminate) the entropy discharged by the productive processes in the environment. Cleaner production techniques reduce the impact of anthropomorphic climate change. Dematerialization and de-energyzation, as proposed, can lead, in an apparent contradiction, to an increase in total dissipation, if the cost of the products is lowered as the result of more efficient processes (Jevons's paradox). To our knowledge *wickedness* has not been clearly associated, as it could, with the nature of complex systems where, as we understand, is the origin of the "mess" to be dealt by choosing a "solution" for a wicked problem.

Some attributes of wicked problems are detailed by Conklin (2005), are:

1) You don't understand the problem until you have developed a solution.
2) Since there is no definitive 'The Problem', there is also no definitive 'The Solution.' (no stopping rule).
3) Solutions to wicked problems are not right or wrong.
4) Every wicked problem is essentially unique and novel.
5) Every solution to a wicked problem is a 'one-shot operation.'
6) Wicked problems have no given alternative solutions.

Conklin gives examples of wicked problems:

- Whether to route the highway through our city or around it?

- How to deal with crime and violence in our schools?
- What to do when oil resources run out?
- What should our mission statement be?
- What features should be in our new product?

Examples of a “tame” problem are also given. According to Conklin, a tame problem,

1. Has a well-defined and stable problem statement.
2. Has a definite stopping point, i.e. when the solution is reached.
3. Has a solution which can be objectively evaluated as right or wrong.
4. Belongs to a class of similar problems which are all solved in the same similar way.
5. Have solutions which can be easily tried and abandoned.
6. Comes with a limited set of alternative solutions.

2. Wickedness and complexity

We propose that the *wickedness* of a problem results from the basic characteristics of complex system, with super-wicked problems corresponding to the highest degrees of complexity, where the variables of the system entangle with intangibles derived from human nature, incorporating the influences of free will, purposiveness, and adaptativeness. The frontier between wickedness and super wickedness of a problem cannot be precisely established, as well as complexity cannot be measured or even defined with precision. Hierarchically, thermodynamics can be ordered in a direction of increasing entanglement, increasing complexity, resulting from the nature of environment-bound (open) systems. In thermodynamics increasing complexity can be conveniently be arranged in the order, classical-> linear irreversible -> nonlinear irreversible. *Dissipative structures*, a term coined by Prigogine, is associated (living and nonliving), with the nonlinear region, the region far from equilibrium, where ordered structures appear and exist. “The multiplicity of solutions in nonlinear systems corresponds to a gradual acquisition of autonomy from the environment “(Nicolis and Prigogine, 1977). Non-living dissipative structures are tornadoes, hurricanes, sea currents. Living dissipative structures are: microorganisms, sea creatures, and humans, understood as the final product of biology. In ecological aggregates we observe the integrated coexistence of adaptative living structures with different degrees of autonomy from the environment, exhibiting different capacities to resist climate change.

The study of complexity theory, emerged and grew, accompanying the drastic change in our view of Nature in the last 50 years, as pointed out by Kondepudi and Prigogine (1998). Their book, “Modern Thermodynamics –*From Heat Engines to Dissipative Structures”*, resulted from decades of work of Prigogine. Modern Thermodynamics, written as an introductory text, was reprinted in 1999, 2002, 2004, 2005, 2006, and 2007. According to the authors, most introductory texts in the field of Thermodynamics, concentrated in equilibrium Thermodynamics, adding that “…from the start the student has to be familiar with ...the contrasting behavior of matter at equilibrium and far from equilibrium”. According to Capra (1997), the change of paradigm, understood to occur by jumps, in discontinuous manner, is defined by Thomas Kuhn as “a constellation of achievements – concepts, values, techniques, etc-shared by a scientific community and used by that community to define legitimate problems and solutions”, (Kuhn, 1970). Discontinue changes emerged in scientific thinking and social and cultural values. The Change in paradigm impacting Ecology include: from rational to intuitive; from analysis to synthesis; from reductionist to holistic; from linear to nonlinear. Changes in values include: expansion to conservation; competition to cooperation; quantity to quality; domination to partnership. The new paradigm "...includes a shift in social organization from hierarchies to networks" (Capra, 1997). The resulting systemic view is one of the most relevant aspects of both of complexity theory and of the wickedness of a problem. The work of Ludwig von Bertalanffy (1968), points out, according to Ackoff, to a wedge "...that could open Science's reductionist and mechanist view of the world so that could deal more effectively with problems of living nature –with biological behavioral and social phenomena for which he believed application of physical science was not sufficient, and in some cases, impossible." It is beyond the scope of this paper to investigate in depth the connection between the concepts of wickedness and complexity -this is a very difficult task, if not an impossible one. It seems clear, however, that the link between wickedness and complexity could be the object of further study. Some of the concepts used by Ackoff and other authors, dealing with the discussion of wicked problems, suggest that wicked problems are a c*onsequence* of the nature of complexity. The key ingredients of complex systems are: teleology; systemic view; holism and indivisibility of the whole; open system or "environment-bound" system, as used by Ackoff, and interdisciplinarity; nonlinearity; incorporation of adaptative sub-systems.

3. Non soluble problems and wicked problems

Gödel

A 25- year-old, Kurt Gödel, logician, was the author of a twenty-five-page paper sent to a journal in 1930, which would change the whole field of Mathematics. According to his proof, delineated in this contribution, there are mathematical statements that cannot be proved or disproved. According to Gödel, mathematical statements exist, even in arithmetic, "…whose validity cannot be decided *without using methods from outside the logical system in question"*, (Coveney and Highfield, 1995). Mathematics cannot be deduced entirely from the axioms of logic. Coveney and Highfield (1995) call this achievement "... a landmark which will remain visible far in space and time." John Barrow is quoted : "If we define religion to be a system of thought which contains unprovable statements, so it contains an element of faith, then Gödel has taught us that not only mathematics is a religion but is the only religion able to prove itself to be one".

Alan Turing

The question of the famous *Entscheidungsproblem* was "Is there always a definite procedure that can decide whether or not a statement is true? " The answer, as proved and given by Alan Turing is "no" – there are limits to what can be computed. See "Turing Machine and Uncomputability", pages 60-70, in Complexity a Guided Tour, Melanie Mitchell (2009). Turing demonstrated the limitations of computability. There is not a computer program that, if asked, will give the correct "yes" or "no" answer to a problem, or even give any answer at all. This class of problems consists in the class of *undecidable problems*.

Non polynomial (NP) problems

A classic example of this class of problem is the travelling salesman dilemma, where the salesman intends to minimize the distance to be travelled, while choosing an order of visits to number N of cities. No computer scientist has produced a well-behaved deterministic algorithm that can find solutions (Coveney and Highfield, 1995) to NP problems. The number of possibilities spirals out of control as the number of cities increase

4. **Conclusion**

As pointed out by Nancy Cartwright (1983) in "How the Laws of Physics Lie", no system of laws can describe the real world, due to its complexity. This affirmation consists in a strong and impacting limitation that has received even more importance later in time, due to the emergence of the theory of complexity. The debate between mathematics and the real world goes on (Coveney and Highfield, 1995). Cartwright establishes a firm limitation to our dialogue with nature: there are problems (as in mathematics) that are rigorously proved to be unsolvable, and there are problems, involving complex systems, that include intangibles, also accepted as unsolvable, even if not rigorously proved unsolvable in a mathematical sense- such as wicked and super-wicked problems.

Wicked problems, involving a large amount of variables, including non quantifiable variables, are problems that admit a set of *alternatives* (called "solutions"), that is, decisions will be implemented on how to act upon the problem to "solve" it, but "solving" has to be understood not in a rigorous, mathematical sense. Wicked problems are problems generated by complex systems, dealing with attributes inherent to the theory of complexity - associated with emergent phenomena; non linear dynamic; environment bound (open systems); subject to chaotic behavior, and adaptative.

There are two classes of problems that deserve to be differentiated here: unsolved and unsolvable. Unsolved, are *open problems*, rigorously formulated, which are in a kind of "waiting list" to be solved. Some of these problems are listed at *Wolfram Web Resources* (Wolfram, Unsolved problems, 2013). There are unsolved problems in the field of mathematics, biology, chemistry, and physics. Two famous open problems, solved last century, were *Fermat's Last Theorem*, and the F*our Color Map Theorem*. The *Poincaré Conjecture* was solved in the beginning of this century.

Considering the particular case of *wickedness,* resulting from a challenge to a group of stakeholders to deconstructing existing energy systems, a definition of *unsolvable* was proposed in the work "ISES 2011: The Evolving Energy Ecosystem ", (Pidcock, 2011): "The term "unsolvable" was used to provoke thought and inspire stakeholders to deconstruct the existing energy system. Upon first glance, certain problems may seem to have feasible or already implemented solutions to them. To challenge the status quo, we should examine how far we are from completely "solving" these problems." What obstacles prevent us from reaching our desired outcomes. While technological solutions or policy mechanisms may exist, barriers created by the conflicting interests of stakeholders may impede the effectiveness of potential remedies."

Conflicting interests of stakeholders, leading fragmentation of a problem, results from the nature of wicked problems, as well as from the different formation and history of stakeholders, reflecting in conflicting policies, and market mechanisms.

Ecology involves a network of open, nonlinear dynamic systems, hierarchically structured, adaptative, highly integrated whole. Ecological systems include living and non-living dissipative structures, entangled with social, cultural, and economic phenomena, constituting wicked and super-wicked problems. Understanding and adequately managing this complex network will positively influence the future of our planet, and contribute to the study of ecological issues as well as to the effort of implementing cleaner production practices. We strongly emphasize that this class of problems –wicked- should be made more familiar to students, as early as possible in their careers.

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