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THE COMPLEX REASONING PARADIGM AS A TOOL FOR ANALYZING PROBLEMS AND BUILDING SOLUTIONS

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Abstract: The article outlines a model of complex reasoning based on four fundamental postulates, derived from the studies of various authors on the subject. It first gives a brief overview of the evolution of the idea of complexity, from its beginnings in psychology and sociology; it then explores the concept of cognitive complexity in more depth, starting with the foundational work of Kurt Gödel, with his study of undecidables (propositions that are accepted as true but can only be demonstrated by ascending to a more comprehensive logical level than that of the mathematical system to which they belong. Two other authors have contributed extensively to the Complex Reasoning Paradigm proposed in the article: Prigogine, with two fundamental ideas: that of the end of simple certainties in science and that of bifurcations as a path to structural changes in complex systems;and Edgar Morin, with his proposal for a complex way of thinking based on three logical operators and the integration of diversity. The article ends with an example of the cognitive advantage of applying the paradigm to the analysis and resolution of problems in complex systems such as those of knowledge societies.

Keywords: Complexity paradigm; bifurcation; Morin's operators; cognitive level.

O PARADIGMA DO RACIOCÍNIO COMPLEXO, COMO INSTRUMENTO DE ANÁLISE DE PROBLEMAS E CONSTRUÇÃO DE SOLUÇÕES

Resumo: O artigo delineia um modelo de raciocínio complexo assente em quatro postulados fundamentais, derivados dos estudos de vários autores sobre o tema. Faz primeiro um breve apanhado da evolução da ideia de complexidade, desde os seus proimórdios na Psicologia e sociologia; explora a seguir, mais aprofundadamente, o conceito de complexidade cognitiva, a partir do trabalho fundacional de Kurt Gödel, com o seu estudo sobre os indecidíveis (proposições que se aceitam como verdadeiras mas que só podem ser demonstradas pela subida a um nível lógico mais abrangente que o do sistema matemático a que pertencem. Dois outros autores contribuíram extensamente para o Paradigma do Raciocínio Complexo proposto no artigo: Prigogine, com duas ideias fundamentais: a do fim das certezas simples na ciência e a de bifurcações como caminho de mudanças estruturais em sistemas complexos;e Edgar Morin, com a sua proposta de um modo de pensar complexo assente em três operadores lógicos e na integração da diversidade. O artigo termina com um exemplo da vantagem cognitiva de aplicar o paradigma à análise e resolução de problemas em sistemas complexos como os das sociedades do conhecimento.

Palavras-chave: Paradigma da Complexidade; bifurcação; operadores de Morin; nível cognitivo.

EL PARADIGMA DEL RAZONAMIENTO COMPLEJO COMO HERRAMIENTA DE ANÁLISIS DE PROBLEMAS Y CONSTRUCCIÓN DE SOLUCIONES

Resumen: El artículo esboza un modelo de razonamiento complejo basado en cuatro postulados fundamentales, derivados de los estudios de diversos autores sobre el tema. En primer lugar, se hace un breve repaso de la evolución de la idea de complejidad, desde sus inicios en la psicología y la sociología; a continuación, se profundiza en el concepto de complejidad cognitiva, partiendo de la obra fundacional de Kurt Gödel, con su estudio de los indecidibles (proposiciones que se aceptan como verdaderas pero que sólo pueden demostrarse ascendiendo a un nivel lógico más amplio que el del sistema matemático al que pertenecen. Otros dos autores han contribuido ampliamente al Paradigma del Razonamiento Complejo propuesto en el artículo: Prigogine, con dos ideas fundamentales: la del fin de las certezas simples en la ciencia y la de las bifurcaciones como vía para los cambios estructurales en los sistemas complejos; y Edgar Morin, con su propuesta de un pensamiento complejo basado en tres operadores lógicos y en la integración de la diversidad. El artículo termina con un ejemplo de la ventaja cognitiva de aplicar el paradigma al análisis y resolución de problemas en sistemas complejos como los de las sociedades del conocimiento.

Palabras clave: Paradigma de la complejidad; bifurcación; operadores de Morin; nivel cognitivo.

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1 INTRODUCTION

The main objective of this article is to formulate a model of analysis based on the paradigm of complex reasoning and to explain its central postulates and its interdisciplinary and multilevel analysis of social problems and human behavior. To this end, we begin by outlining the trajectory of the idea of complexity in psychology and other behavioral sciences, before moving on to the work of the authors who are the pillars of the complexity paradigm in today's scientific environment.

Psychology tackled the problem of human cognitive complexity as early as 1955: Bieri (1955) was concerned with cognitive complexity and its effect on predictive capacity; Kelly (1955) investigated cognitive complexity in personality structuring; Nidorf and Crockett (1965), Karlins et al. (1967) and Schröder (1971a) continued these studies, exploring the effect of cognitive complexity on creativity, conflict resolution and personality structure. In the area of organizational behaviour, Mitchell (1971) studied the effect of cognitive complexity on team productivity; and Streufert and Streufert (1978) and Streufert and Swezey (1986) explored the impact of contextual complexity on organizational behaviour. Other authors, such as Hooijberg, Hunt and Dodge (1997), Lichtenstein and Plowman (2009), Schneider and Somers (2006), Uhl-Bien and Marion (2007), or Parreira, Pestana and Oliveira (2018) have adopted the complexity perspective to study complex models of leadership and the organization of complex systems. Psychology's contribution to understanding and applying the paradigm of complex thinking cannot be ignored (Streufert, 2006).

These studies are part of a variety of models, but they all have some common bases:
- our mind is made up of interrelated cognitive processes, responsible for the organization of our knowledge;
- these cognitive processes occur in a certain, albeit flexible, order; but the concern with method, a central issue in the approach to cognitive complexity approach (Neufeld and Stein, 1999), is a clear feature;
- they are not restricted to the neurological support substrate, although they depend on it and its organization: the mind is a processor of symbols and meanings, which it relates to objects in the context;
- the human relationship with the external world is therefore intentional and autonomous.

We can't forget the contribution of scholars of economic organizations, such as Herbert Simon, with his work on the limited rationality of our decisions (Simon, 1987), as well as on the architecture of cognitive complexity (Simon, 1962); von Neumann for his studies on cybernetic systems; the work of Albin and Göttinger (1983) on complexity in the field of economics; chemical and biological scientists, such as Prigogine and his colleague Nicolis (1989); and sociologists such as Edgar Morin (1977; 1990; 2001; 2011) and Le Moigne (1999) in the epistemology of the social sciences. All of these authors paved the way for the knowledge we enjoy today; but, as Bernard de Chatres said, if our eyes can reach very distant horizons, it is because we are sitting on the shoulders of giants - Gödel, Prigogine and Morin - the three thinkers who are the pillars of the Model proposed in this article.

Gödel's foundational work

The complexity paradigm, whose first foundation can be found in the work of Kurt

Gödel (1931) on the incompleteness of the demonstrability of propositions recognized as true within a logical system, has received theoretical contributions over time from various authors. His work on the demonstration of undecidable propositions and the formulation of incompleteness theorems had a discreet repercussion; but it was the first stone in the new style of thinking that would be affirmed throughout the 20th century in various scientific fields.

In an article in honor of the centenary of Gödel's birth, Alkaine states that Gödel's work shows the limits of reason and should therefore "be taken into account in modern areas of the exact sciences, because his work has greatly affected the way we think today" (Alkaine, 2006, p. 526). Gödel showed that the appearance of paradoxes in mathematics is inevitable; and to keep the system consistent with itself, they must be accepted as undecidable: "propositions that cannot be decided as false or true within the system itself, but only from an external conceptual field. This is the price to pay for the consistency of the system" (Kubrusly, 2006, p.8). As Gödel argued at the Königsberg Congress on the Epistemology of the Exact Sciences:
(1) If a formal system containing arithmetic is consistent, then it contains true arithmetic propositions which, however, are undecidable;
(2) There is no computable procedure for proving the consistency of the theory itself (Lannes, 2014, p.4).

The truth or falsity of an undecidable will always have to be based on a more comprehensive and less restrictive logic than that adopted for the mathematical system in question (Kubrusly, 2006). The impact of these two theorems turned out to be a liberating influence, when they unleashed a new style of thinking in epistemology (Fleck, 1979, cited in Lannes, 2014); and this impact led precisely to a change in attitude towards the domain of science today, the arguments with which we intend to affirm it, its limits and even the fragilities of its roots. Gödel's work showed that the logical foundation of an interpretative system of reality must be sought in a conceptual system of broader rationality. This requirement places Gödel as the primary source of the complex thinking paradigm, as can be seen in von Neumann's letter to Gödel (quoted in Ferreira, 2006, p. 1):
I must testify to all my admiration (...): you have solved this enormous problem with masterly simplicity (...) to show that the consistency of mathematics is not demonstrable (...) Reading your study was truly an aesthetic experience at the highest level.
The aim of this article is to highlight the impact of this new style of thinking and transpose the practices it advocates into the realm of the social sciences (Lannes, 2014). To do this, it explores the contribution of thinkers who are the pillars of the complexity paradigm and have led to the change in attitude that is at the heart of scientific thinking today.

Prigogine's contribution

Prigogine is responsible for three main ideas that have helped broaden the horizons of scientific thought to incorporate the idea of complexity:
- the end of certainties in science;
- the concept of dissipative structures as a source of structural change;
- the idea of bifurcation, which opens up possible alternatives for structuring things, and enriched the meaning of process change with the idea of history.

For Prigogine, the end of certainties does not mean the empire of ignorance; what he stresses is that this new vision leads us to put aside “the tranquil certainties of traditional dynamics” (Massoni, 2008, p. 2308-7). In their place, Prigogine proposes that science incorporate indeterminism, which acquires a precise meaning: it is not the absence of predictability, but knowledge of the limits of predictability (Prigogine and Stengers, 1997), not stating what is certain, but what is possible; and this possible is the new meaning of the laws of nature (Massoni, 2008). Consequently, determinism breaks down, because everything is in motion in this universe of complex systems, with multiple possibilities open to any system (Prigogine and Stehgers, 2009). This is why probability is directly linked to uncertainty or, if the term is preferred, indeterminism. On the other hand, the questions addressed in science are not eternal, they are linked to a certain historical time (Carvalho, 2017), they result from the questioning of previous knowledge and the growing disillusionment caused by the answers it offers (Bachelard, 1940). This is the end of neutral and apparently timeless certainties, not the end of knowing what is complex. It simply breaks the symmetry of temporal reversibility and integrates entropy as one of the indicators of the irreversibility of time. The awareness that the field of science today is not one of the tranquil certainties of classical determinism grows stronger: the new state of matter (far from equilibrium, which cannot be described by linear equations) forces us to see the world around us in a different light, the phenomena of life, of time, of the multiplicity of structures. Scientific reasoning leaves the field of the limited certainty of linearity (Simon, 1962; 1987) and enters the space of multilinear possibilities to be explained, in line with Gödel's undecidables.

The idea of dissipative structures and bifurcations

Prigogine considered bifurcation to be the most important characteristic of complex systems, because “bifurcation is the critical point through which a new state becomes possible in nature” (Prigogine & Stengers, 1997, p. 122). Bifurcations arise from two moments: disordered and turbulent movements due to forces that cause a state of disequilibrium in the system and push it to the brink of chaos; creation of dissipative energy structures that cause the state of disequilibrium. Dissipative structures allow order to emerge from chaos, from entropic movements, by the system entering one of the possible bifurcations open to the future:

> Each complex being is made up of a plurality of entangled times. In this way, history as a process - of a living person or a society - is never reduced to the monotonous simplicity of a single time. (Prigogine, Stengers, 1997, p. 211)

In the succession of bifurcations, there are alternating deterministic zones - between bifurcations - and points of probabilistic behavior, the bifurcation points; at these bifurcations, there are usually many possibilities open to the system. The emergence of new structures is rooted in energy-dissipating structures. This emergence implies time in a definite direction, which led Prigogine (1980) to state that the logic of the irreversible processes of systems far from equilibrium is not a logic of equilibrium, but a narrative logic, i.e. that the activity of dissipative structures is defined as history and not just as a balance of energies. The result is a breakdown of determinism, even on the macroscopic scale (Prigogine & Stengers, 1984).

The multiple possibilities open to the system cannot be reduced to a single scheme:

> The system can never be explained from the simplicity of a single time path: it has become complex because it is made up of a plurality of times in which the past, present and future are intertwined. Any state of the system is not something that can be deduced, because others were also possible. The explanation must be historical or genetic: to describe the path that constitutes the system's past, to list the crossed bifurcations and fluctuations that decided the real history, among all the possible ones. (Prigogine, Stengers, 1997, p. 124)

Bifurcations introduce time as a fundamental variable: time can no longer be ignored, even in physical chemistry, where entropy is the indicator of irreversible temporal movement. Eddington (1928) called it the arrow of time, because it indicates the degradation of the energy and matter that constitute them. In living systems, which in addition to energy and matter exchange information with the environment, the emergence of new states (negentropy, as Morin called it) is another indicator of the arrow of time. The arrow of time is the way we live it, a subjective perception of what we are: the irreversibility of time is a function of movement in a finite system, subject to entropy processes, whose logic is narrative, not symmetry. Knowing a complex system requires knowing its past and calculating its future, based on a careful view of its past and present. The system is a totality of time[1].

The multiple choices at the forks define the degrees of freedom and intrinsic creativity of complex systems, and force us to incorporate uncertainty as a component of knowledge, no longer as a negative stance, but as a way of seeing reality. A way that is more attentive to its multiple planes, more open and questioning, in which the certainty of what is known contains the awareness of its limitation, its uncertainty, typical of all finite systems (Tarsky, 1933, quoted in Sher, 1999, p. 150). By making a scientific contribution to the end of limited and limiting certainties, Prigogine continued Gödel's reflection on the inherent limitation of logical systems and the need to move towards higher conceptual systems, as a condition for understanding complex realities. By studying the emergence of order from states close to chaos, due to dissipative energy structures and the opening of bifurcations, Prigogine took a decisive step towards explaining the changes that lead to the emergence of new structures and new meanings, an essential component of the dynamic complexity of systems. Finally, with the idea that time is an irreversible path for living systems and that these can only be understood as complex history, Prigogine introduces another essential factor for complexity, in line with the dialogic and recursive principles proposed by Morin to understand the circular processes that build the total complexity of systems.

Morin's fundamental contribution

Edgar Morin is the most notorious author associated with the paradigm of complex reasoning (Morin, 1990). According to him, all human activity obeys a tetralogy of relationships: order, disorder, interaction, (re)organization (Morin, 2011). Order and disorder must be understood as a pair in a dialogical relationship, which produces new configurations from the interaction of the parts and their reorganization. In this process, cause and effect

[1] Parafraseando Heidegger (1977), se o *Dasein* humano é um ser para a morte, só no final do seu tempo irreversível, a sua história, ele resolve a angústia do seu existir, ficando completo e não mais mutável na sua identidade (que fixa a sua totalidade como *Dasein*).

interact in a reciprocal movement, which opposes the simplicity of linear causality: time allows effects to feedback on their causes, forming a complex multidirectional causal circle. The complexity of a system therefore results from the multiplicity of its conditions and the variety of its movements (interaction and reorganization). The internal diversity of a system, the variety of its component parts, can be considered the first criterion for assessing complexity (static complexity); the variety of internal movements adds to the diversity of the parts in the construction of the whole, as stated by Kochugovindan and Vriend (1998, p.56): "complex systems ... are based on a large number of agents, which interact with each other in various ways ... and modify their actions according to the events of the interaction process" (dynamic complexity).

To understand the complexity of reality, Morin proposes a method, which he himself rooted in three theories (Morin, 2011): systems theory, and the idea that the whole is superior to its parts, since it exhibits emergent qualities; information theory, which places us in a universe where order and disorder coexist, where information has the role of creating new realities; cybernetics, which highlights feedback processes: one (negative feedback), responsible for the stability of the system; the other (positive feedback), responsible for its change. From these roots, Morin developed the methodological principles of complex thinking, which form the framework of what he called the paradigm of complexity and which he proposes as an instrument for understanding reality. In his words,

> disorder translates into uncertainty (...) it brings chance, an inevitable ingredient of everything that seems disorderly to us (...) every process of order occurs through a greater disorder - related to the second principle of thermodynamics (...)) as a consequence, the disorder (entropy) of the universe is always increasing (...) agitation, random encounters are necessary for the organization of the universe and it is by disintegrating that the world organizes itself - this is a typically complex idea, because it unites the two notions, order and disorder. A strictly deterministic universe would only be order, it would be a universe without innovation, without creation. (Morin, 2001, p. 87)

The logical requirement for this form of reasoning is to avoid any simplifying thinking: it is clear that a reality that is organized in a complex way requires, for its understanding, complex thinking, which ... must go beyond closed entities, isolated objects, clear and distinct ideas, but also not be confined by confusion, vaporousness, ambiguity, contradiction: it must be a game / work with / against uncertainty, imprecision, contradiction (Morin, 2001, p. 87).

Morin (2011, p. 141) uses this logic in the tetrology to explain the recursive circuit: complementary relationships (societies, associations, mutualisms), competitive relationships (competitions and rivalries) and antagonistic relationships (parasitism, depredation):

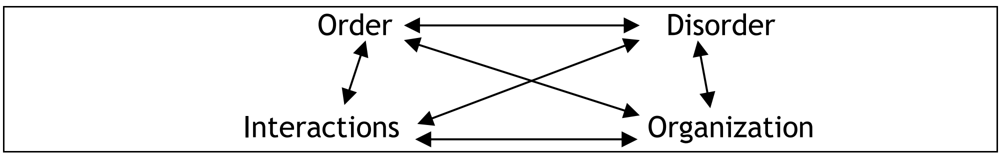

Figure 1 - The Tetralogical ring - Source: Morin (2011, p. 141)

The idea of complexity is not intended to replace concepts such as clarity, certainty, determination and coherence with those of ambiguity, uncertainty and contradiction: it is based on the interaction and mutual work between these principles (Morin, 2001, p.88). It requires a strategic vision (not just a tactical or operative one) which Morin defines as the art of "using the information that emerges during action, integrating it, formulating action plans and gathering as much certainty as possible in order to face the uncertain" (Morin, 2001, p.90). To put the tetralogical ring into practice, Morin proposes three conceptual operators: dialogical, recursive and holographic.

The dialogical operator

The dialogical operator (which Morin considers to be superior to the concept of dialectics) consists of identifying the different parts of the system as precisely as possible, in order to connect what seems separate or even contradictory. The systematic use of the dialogic operator is fundamental to thinking about reality, to grasping it in its unity and multiplicity, not trying to explain it by its particular elements, which is reductive. This will help us to achieve a "true, open rationality, dialoguing with a reality that resists it, a rationality that is aware of its shortcomings" (Morin, 2011, p.23). In order to do this, it is essential to understand diversity and develop concepts that allow us to build unitas multiplex: the unity of the whole that does not suppress, but on the contrary, takes advantage of diversity.

The recursive operator

The recursive operator is related to the negative and positive feedback processes proposed by Wiener (1961). For Morin, recursive causality is not limited to processes of regulation or expansion of deviations; it is ontological, it is an instrument for building the complex system itself:

At a higher level, recursion is translated by consciousness, the ultimate emergence of complexity, proper to the human spirit (...) consciousness is reflexive, it implies an incessant return to the thoughts that produce it, in order to transform them ... providing the faculties of doubt, of self-examination ... consolidating in us the uniduality of the subject observed and the subject who observes (Morin, 2011, p.143).

It's not about a linear relationship - cause/effect - but about understanding the interactions that unfold the system and make it evolve, as a whole and in its parts, as it builds along the arrow of time (a spiral arrow, where setbacks are present overvaluations of the weight of past causes).

The holographic operator

According to Morin himself, the idea for this operator came from systems theory and directly from contact with Atlan and his ideas about self-organizing chance and the autopoiesis of complex living systems (Atlan, 1994). The self-organization of the system as a whole results from the emergence of components and integrating qualities through the recursive process. Therefore, holographic reasoning requires an effective knowledge of these components and the perception of their contribution to a different whole, which receives meaning from its parts, but which also gives each of them a meaning of its own. The whole is not a pot pourri of confused ideas, but the clarity of the particular in the whole and the clarity of the whole in the particular. It is the effort to understand the complexity of a reality that can only be properly understood in this dialogical junction of opposites.

Thinking about reality and knowledge based on these operators is at the heart of Morin's ideas on complexity. His reflection includes the essential epistemological acquisitions of the authors who have explored this paradigm:
- the lesson of Gödel's paradox: in order to explain a complex phenomenon, knowledge must be sought outside of it (in context, in higher-level models); otherwise, the system will always contain undecidable propositions, which we believe to be proven, but which cannot be demonstrated within the system;
- Prigogine's concept of dissipative structures and bifurcations, which allows us to understand the emergence of a new order with a new meaning, expressing the dynamic complexity of the system;
- the belief that humans should be operators of complexity, capable of overcoming simple intradisciplinary reasoning and building a multidimensional structure,
interdisciplinary science;
- the idea that information is a tool for reflexivity, self-reference and creativity, because it is the articulating axis of the constructed real (subject-object): it "allows us to move beyond the paradigm of classical science and logic, without rejecting them, but integrating them into the paradigm of complexity" (Morin, 2011, p. 151). This opens the door to other levels of reality (Nicolescu, 1999) and new insights on the spiral path of knowledge construction.

Um modelo de raciocínio complexo para análise de sistemas e problemas

Partindo das ideias propostas, delineiam-se quatro postulados, que definem o Paradigma do Raciocínio Complexo (PARC), para a análise e avaliação de sistemas e problemas nas ciências humanas e sociais. O primeiro postulado do Modelo define a complexidade estática (estrutural) de um sistema e é baseado no operador dialógico de Morin, de que o todo não é um conjunto homogéneo, emerge a partir de componentes diversos e por vezes até contraditórios, cuja diversidade não pode ser ignorada, já que é a partir deles que se constroi o todo. Esta ideia fundamental implica a rejeição do reducionismo cognitivo da realidade, que erradamente conduz a uma definição do real baseada numa visão parcelar, gerando uma percepção truncada da totalidade do sistema, ao inibir a visão de propriedades que emergem das partes diversas não percebidas, mas também contributivas para a configuração do todo. Mas o todo não é uma simples soma daspartes, emerge delas e, por isso, é ao mesmo tempo mais e menos do que a soma de suas propriedades.

O primeiro postulado do PARC assenta na conjugação dos contributos de Morin e Kaufmann (1995).

PARC's First Postulate: the construction of a system's complexity

> The greater the number of different parts of a system from which the overall identity emerges, the greater its complexity (static complexity).

If we want to understand a system or a problem in depth, we need to understand each of its various components and how each contributes to the whole that emerges from them.

As Morin pointed out, the whole is not a pot pourri of confused ideas, but the clarity of the particular in the whole and the clarity of the whole in the particular: it aims to obtain all the certainty possible by accepting all the uncertainty inherent in it. This first postulate states the first source of a system's complexity, precisely the parts or components that determine the level of its static complexity. Kaufmann (1995) drew up a formula, the first two variables of which define this level: N, the number of components in the system; P, the common elements between the components that guarantee the emergence of the totality.

PARC's second postulate combines Prigogine's ideas - the emergence of new configurations in systems far from equilibrium, due to the dissipative structures of energy - and Morin's ideas about recursive processes and the tetralogical ring (the interactions that create order/disorder, organization/disorganization). But in addition to these internal dynamic movements, the postulate also includes the external dynamic of interactions with the context, which integrates physical, economic, social, cultural and political factors. These movements within the system, and of the system as a whole and its parts with the context, constitute the second matrix of the system's complexity and determine its dynamic complexity. Taken together, the two dimensions of complexity establish the system's overall visible level of complexity. Two other variables in Kaufmann's formula express this dynamic complexity: K, the level of interaction of the system's components; C, the interactions of the system and its components with other entities in the context.

PARC's Second Postulate

> The internal and external movements of the system define its history, subject to the process of irreversibility of time, whether they are entropic or negentropic movements. The greater the variety of these movements, the greater, ceteris paribus, the complexity of the system (dynamic complexity).

But there is yet another criterion for defining the level of complexity of a system: the way in which the diversity of parts is integrated into a system with its own identity. The system is not the mere sum of its parts, it is constructed as a unitary whole, continually emerging from the interaction of these parts, integrating the nature of each of them into a new nature, its own as a system. This is why Morin called it unitas multiplex, a unity of multiplicity:

> The unity of the system is not the unity of unum ... It is simultaneously one and not one. There is a gap and a shadow in the logic of identity. We have already seen that there is not only diversity in the one, but also relativity in the one, alterity in the one, uncertainties, ambiguities, dualities, splits, antagonisms. (Morin, 1977, p. 140)

The processes of articulation and integration of these parts, emerging from distinct patterns of behavior, are therefore nuclear. The integration of diversity into unity can be achieved through two processes: the use of energy (power, in human systems); and the use of information, which articulates diversity through the discovery and use of adjustment processes. Morin widely defends the role of information in the construction of complexity[2]. In his matrix idea, achieving the unity of a system through the use of power leads to a more or less extensive reduction in diversity, since unification through the use of power is based on the overvaluation of some components, minimizing the contribution of others; building unity while maintaining diversity is only possible by learning new, more comprehensive forms and through a systematic exchange of information, until a suitable format is found. This new format, therefore, necessarily integrates more information than the previous ones. This is the idea behind the Model's third postulate.

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PARC's Third Postulate

The more a system's identity emerges from its components through the use of information rather than energy (power), the greater its internal variety, its level of information and interaction and, consequently, its total ontic complexity.

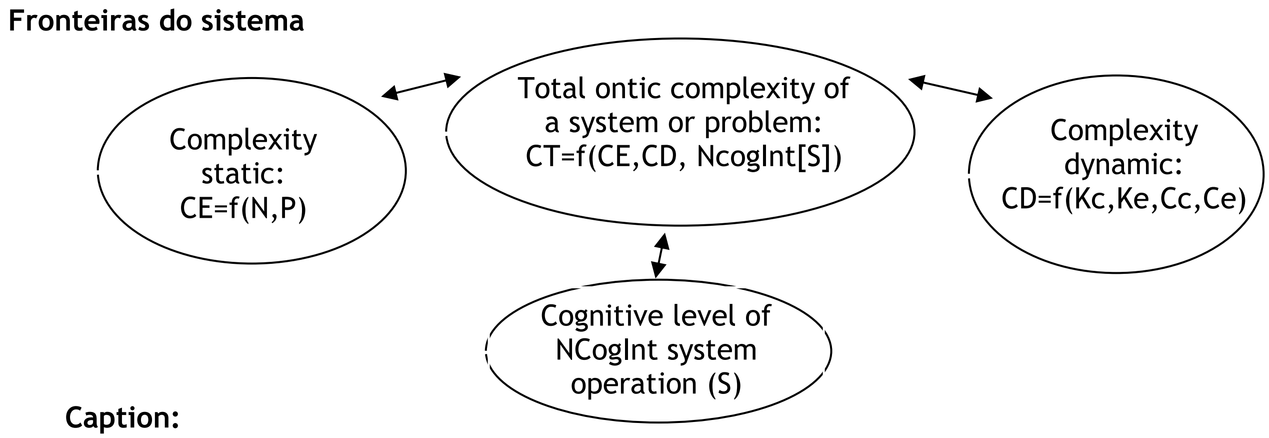
Thus, the substantive complexity of a system can be assessed on the basis of its position in the criteria established by the three previous postulates; we only need a scale of levels of knowledge in order to know at which level to situate its analysis. The fourth postulate of PARC expresses the cognitive conditions of the complex reasoning paradigm. But before we go any further, it would be interesting to present the PARC formulas that express the construction of the total complexity of a system or a problem, set out in the three postulates explained above (fig. 2 and fig. 3).

[2] The proposed model conceives of information as one of the three components of observable systems (matter, energy and information), with energy and information being the organizers of matter, defining its structure and processes. The modeling of structures through energy (power, in human systems) results from a clash of forces, which leads to the imposition of structures associated with the force of greater intensity. But these structures may not be any more positive than those that already exist; they may even be of inferior quality, if they result from lower levels of knowledge. On the other hand, if change is carried out on the basis of information processes, the resulting structures and processes will be of higher quality, because information is used as knowledge (=information put into action, as explained by Davenport and Prusak, 1998). Information made knowledge allows us to reach the cognitive level needed to understand and intervene positively in changing the structures and processes of complex social systems, a central idea of PARC.

Figure 2 - Kaufmann's formula for the complexity of a system or problem

CS,P = f(N,P, K,C)
Where: N, the number of components in the system (static complexity); P, the common elements between the components, which ensure the emergence of Totality (static complexity); K, the level of interactions of the components (dynamic complexity); C, the interactions of the system and its components with other entities in the near and wider context (dynamic complexity).

Figure 3 - PARC model - The ontic complexity of a system and its factors



Caption:
EC - static complexity
N - number of system components (Kaufmann)
P - the common elements between the components (Kaufmann).
DC - dynamic complexity
Kc - level of competitive (power-based) interactions within the system
Ke - level of resolving interactions (based on information) within the system
Cc - level of competitive (power-based) interactions between the system and the context
Ce - level of resolving interactions (based on information) between the system and the context
CT - total system complexity.
NcogInt - cognitive level of interdisciplinary operation.

Source: The authors (2020)

The fourth postulate is rooted directly in Gödel's undecidables and was translated into operational terms by Gell-Mann, in his criterion for assessing the complexity of a system: we know that the complexity of a system or problem is greater the more extensive and difficult its verbal or mathematical description is (fig. 4).

PARC's fourth postulate

In order to understand a system or solve a problem with a certain level of informational complexity, cognitive complexity of a level equal to or greater than the informational complexity of that system or problem is required (required cognitive complexity - RCC).

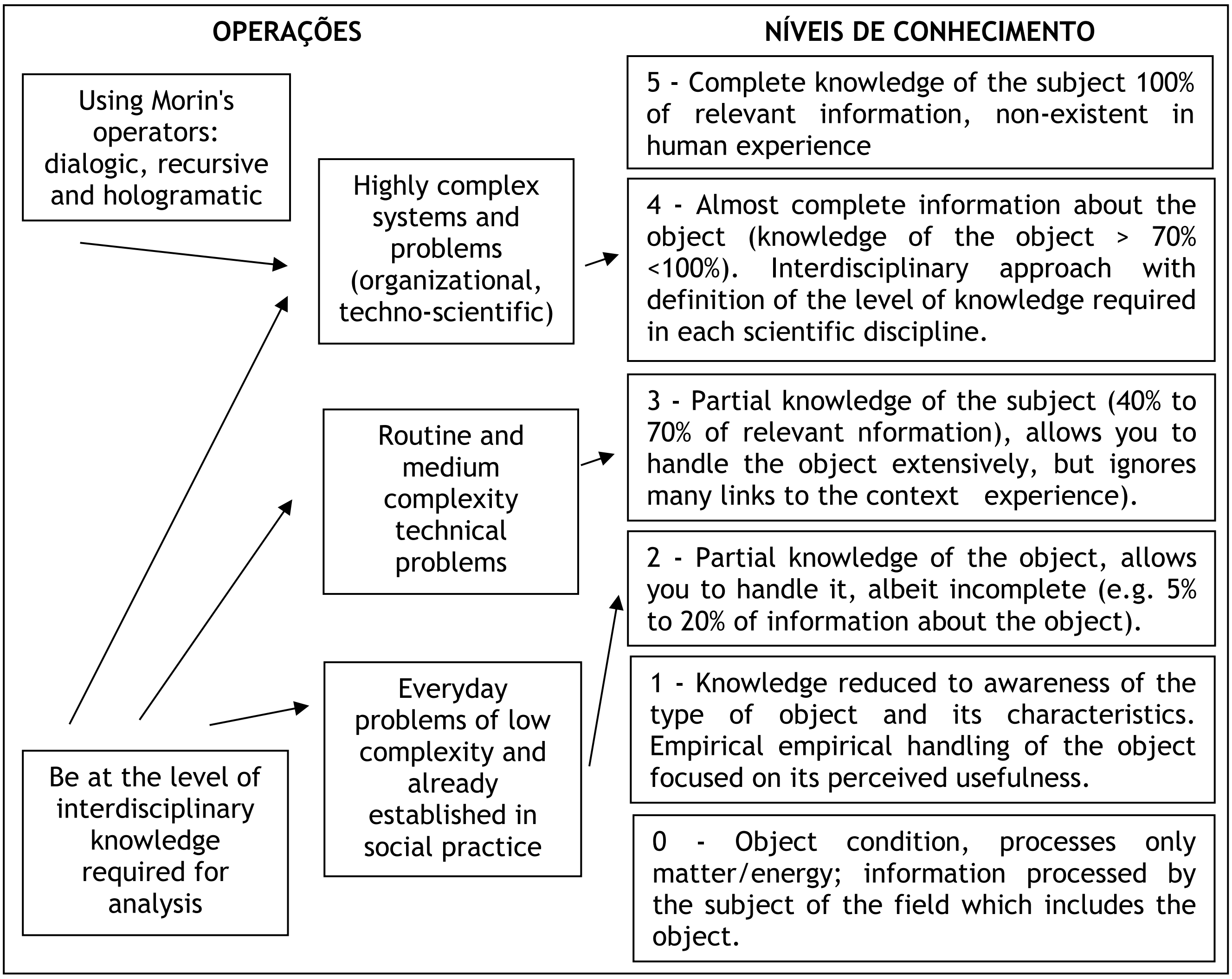
Figure 4 - PARC model - the formula for the fourth postulate

CCR ≥ NcogInt (S,P) - Cognitive level required to analyze and decide on a system or problem
Caption:
CCR - cognitive complexity required for the complex analysis of the system or problem.
NcogInt(S,P) - interdisciplinary cognitive level of the operations of a system or problem.

Source: the authors

The postulates set out above and the formulas that complete them (figs. 2, 3 and 4) indicate the cognitive level at which we must be situated if we want to explain a complex system fully and accurately or solve its problems effectively, without perverse effects. Figure 5 shows the various possible levels of cognitive complexity and the conditions for level 4, which is typical of current science.

Figure 5 - PARC model - Guaranteeing the cognitive level required today to analyze a complex system or problem



Source: The authors (2020)

Adjusting the cognitive level to the ontic complexity of a system or problem is what makes it possible to avoid perverse effects (of lesser or lesser magnitude), both in the interpretation and analysis of a system or problem and in any decision to intervene in reality. But our understanding of the objects in the field can be based on any cognitive level from 1 to 4. Most of our day-to-day relationship with the objects in our context is based on cognitive levels 1 and 2, which are sufficient for us to manage the probabilities of this relationship; at a professional level, we often operate at level 3, since at this level our behavior is at a more technical level, which is usually the level required for us to act correctly. Only when the level of complexity rises to a scientific analysis requirement do we rise (not always, hence the potential perverse effects) to cognitive level 4.

Applying complex reasoning to the analysis of the impact of management policies and the school context on the behavior of teachers at a university

1. Comparison of three cognitive levels of analysis

1.1 Level 2 analysis, the most common in everyday life

a) Data source	Personal observation of attitudes and behavior, over a period of time, when interacting with situations; information from third parties.	Lack of perception-guiding models; insufficient quantitative and qualitative data
b) Level of interpretation	Common sense empirical knowledge; lack of theoretical models of analysis.	Quality of analysis with significant flaws.
c) Accuracy of conclusions	Low, subject to errors due to probabilistic judgments perceived as certainty; great difficulty in self-correction.	

This analysis is what we call common sense and is more or less sufficient for us to act appropriately in the various contexts of our personal and professional lives. Obviously, the richer our experience, the fewer mistakes we make. But it's a level of knowledge of reality that doesn't allow us to make decisions on very complex problems without taking relatively serious risks.

1.1 Level 3 analysis, common in classic theories of psychology (20th century)

a) Data source	Observation of behavior; interviews and various tests.	Abundant data in quantitative terms and medium diversity in qualitative terms.
b) Level of interpretation	Scientific-type knowledge, with a theoretical and statistical basis focused on a preferred model of a specialized type	Quality of analysis with significant successes; but with flaws due to theoretical deficits associated with monospecialization
c) Accuracy of conclusions	Average; controlled probabilistic conclusions; errors due to imperfect theories; self-correction dependent on theoretical revisions	

1. Level 4 analysis underway in 21st century behavioral sciences

a) Source of data	Observation of behavior; interviews; various tests; experimentation; in-disciplinary guided observation.	Abundant data on a quantitative level; search for the maximum diversity that can be integrated on a qualitative level.
b) Level of interpretation	Interdisciplinary scientific knowledge, with an advanced theoretical and statistical basis; complex systemic vision.	Quality of analysis with significant successes; attention to the prevention of interpretative errors, through interdisciplinary vision.
c) Accuracy of conclusions	Medium plus and high, controlled probabilistic conclusions, with possible errors if there are flaws in the interdisciplinary vision; continuous self-correction, systematic theoretical review, integration of innovations.	

2. The practice of level 4 analysis, based on PARC

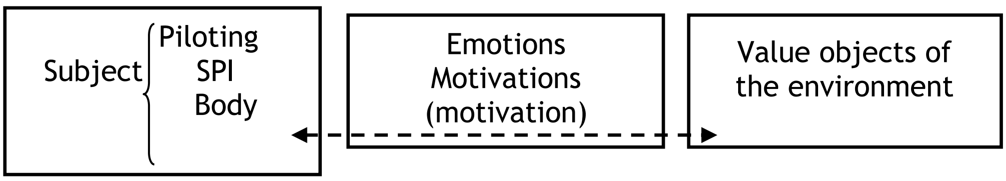
2.1 First step in the analysis

The first step in a PARC-based analysis is to identify the system to be analyzed in terms of its fundamental characteristics and the components that structure it as a system. In this case, the problem to be solved is:
Knowing how to explain the impact of contextual factors on the behavior of teachers at a university.

The first step in this analysis will therefore be to highlight the theoretical framework that allows us to understand and explain the behavioral style of teachers, in order to assess the extent to which it is influenced by the behavioral patterns of the components of the school context: managers, students, support staff, physical spaces and equipment.

Figure 6 shows the human subject as a system in a vital relationship with its context:
- These relationships are conditioned by emotions, which are transformed into motivations for action for action, by the emotional impact exerted by the objects in the environment (which is why Lewin (1936) called them objects of value).

Figure 6: Symbiotic relationship between subject and environment



Source: Pestana, Parreira and Moutinho (2019), adapted from Nuttin (1980).

According to this model, the human subject is a system made up of three major subsystems (which are subdivided into 19 smaller specialized subsystems (Miller, 1978), on the basis of which it establishes a vital unity with its supporting context:
- all its behavior is conceived as an essential relationship with the environment, made up of all the objects, people, conditions and events that the subject faces and interacts with. with which they interact;

- These relationships are conditioned by emotions, which are transformed into motivations for action for action, due to the emotional impact exerted by the objects in the environment (which is why Lewin (1951) called them objects of value).

The interdisciplinary analysis (level 4) of the behavior of the subjects included in the university system (teachers, managers, students, support staff, physical spaces and equipment) involves the following scientific areas:
- specialties of medicine, neurosciences;
- psychology: cognitive psychology, emotions and motivations, reasoning models, social of reasoning, social behavior;
- Psychology of values and action criteria; decision theories; psychology of consciousness and identity.

1.2 Second step: analysis of the various contextual factors and their impact on the individual

a) Inventory of structure, process and management factors
- Physical structure of the spaces and work tools available to the teacher;
- Organization of teaching and learning time with students;
- Working climate within the teaching team and in interaction with managers;
- Culture promoted and experienced in the institution;
- Policies for managing educational processes and the creation of knowledge;
- The University's human resources management policies, namely: remuneration process professional development, career progression and social affirmation of the role of the teacher social affirmation of the role of the teacher.

b) Characteristics of students attracted to university
- Cognitive and attitudinal preparation for entering higher education;
- Climate promoted within the student body and between students and teachers;
- Promoted and consolidated student culture;
- Type and level of motivation for study.

c) Accurate recording of behaviors derived from the impact of the context
- teacher behavior (pedagogical quality, citizenship attitudes);
- student behavior (learning style, relational quality);
- behaviors of educational assistants and support staff (technical attitudes).

d) Relationship between the variables in a), b) c) and their impact on the socio-cultural and educational configuration of the institution.
Statistical analysis of correlations and causal probabilities (Anova, Manova, SEM).

Third step: maintenance or alteration of the behaviors that make up the subject's style

Evaluate the intensity of the motivators to maintain and the motivators to change, based on the data collected and its interpretation using the formulas of the complex reasoning model.

Fourth step: decision to intervene

Define an intervention plan with the measures designed to improve the teachers' pedagogical and citizenship behavior, based on the complex analysis carried out. It is hoped that an analysis guided by the PARC recommendations will succeed in outlining positive solutions without perverse effects. The knowledge obtained will form a solid basis for ensuring control of the internal and external effects of the decisions taken, ensuring solutions that are likely to be free of perverse effects.

An open conclusion

As an open conclusion, we highlight the aim of this article: to highlight the impact of the complex reasoning paradigm and transfer it to social and behavioral research practices, as recommended by Lannes (2014). The flexibility of complex thinking makes it possible to adjust the model to a wide variety of problems, including the complexity of real problems, where the data is certainly much more tangled than that shown in the chosen example, requiring undoubtedly more powerful tools, with a more cumbersome and complicated process. But we hope that the level of complexity has been sufficiently highlighted: an interdisciplinary multi-level analysis, to capture the complexity of the problem and ensure more informed decision-making, at a higher conceptual level and therefore less likely to generate perverse effects. Focused on these results, the authors are willing to continue the study, convinced that the paradigm of complex reasoning is a promising tool for tackling the challenges arising from the expansion of new technological systems in all fields of human life.

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