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Contemporary Science and the Call for a Dialogical Epistemology

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Abstract:

The science of today has undergone significant transformations that have challenged classical epistemological models of linear causality, disciplinary closure, and the pursuit of absolute certainty. The increasing role of the complex, the interdisciplinary, the uncertain, and the modelling has highlighted the limits of classical reductionism and monology. In this context, the current article aims at substantiating the need for a dialogical epistemology that is sensitive to the complex, dynamic, and historical nature of scientific rationality without succumbing to the risks of epistemological relativism.

The main thesis of this study is that dialogical epistemology can offer an adequate epistemological model for modern science only if it is developed through a critically regulated synthesis between the epistemology of complexity developed by Edgar Morin and critical rationalism developed by Gaston Bachelard. Although the complex thought developed by Morin allows scientific rationality to be opened up to dialogue, plurality, and uncertainty, critical rationalism developed by Bachelard offers the epistemological mechanisms that allow this opening to be regulated through conceptual rigor, epistemological rupture, and scientific normativity.

From a methodological point of view, this article is based on a critical-analytical-synthetic approach. After providing an operational definition of dialogical epistemology, which is distinguished from a positivist epistemology, pure hermeneutics, and epistemological relativism, this article presents an analysis of the epistemology of complexity, with a focus on its dialogical, recursive, and hologrammatic principles, as well as a critical discussion of its epistemological limitations. In a second step, this article presents an analysis of Bachelard's critical rationalism, with a focus on

epistemological rupture, applied rationality, and rational pluralism as tools for regulating scientific dialogue.

The article concludes by advancing a model of dialogical epistemology based on the idea of critically regulated dialogue, methodological pluralism, and the productive integration of uncertainty. The importance of the implications of such a dialogical epistemology for interdisciplinary research, scientific ethics, and current epistemology is highlighted. The dialogical epistemology is seen to articulate openness and normativity, and complexity and critical regulation, in a way that is coherent and rigorous.

Keywords: Dialogical Epistemology; Contemporary Science; Complexity; Critical Rationalism; Edgar Morin; Gaston Bachelard; Methodological Pluralism; Scientific Rationality; Uncertainty.

Contemporary Science and the Call for a Dialogical Epistemology

1. INTRODUCTION:

Modern science is no longer viewed as a neutral form of cognitive activity, directed toward the discovery of an objective truth that exists independently of the subject of knowledge. Instead, it has been viewed as a complex form of human activity, in which theoretical, linguistic, historical, and social elements are closely interconnected. The dramatic changes that the sciences have experienced in the twentieth century, especially physics, biology, and the humanities, have made it clear that the classical vision of science, based on empirical certainties, rigid rationality, and the dichotomy between the subject of knowledge and the known object, has reached the limits of its applicability.

In this context, modern philosophy of science has had a crucial role in undermining the epistemological basis of positivism, showing that scientific knowledge is not a continuous construction of facts, but rather a problematic construction, characterized by discontinuity, rupture, and methodological pluralism. Gaston Bachelard marks an important turning point in this evolution of the philosophy of science, as he underlines the non-certain character of scientific knowledge, as well as the idea that scientific progress is only achieved through epistemological ruptures, surpassing cognitive obstacles, and transforming the relation between reason and reality.

However, the complexity of modern science does not merely reside in the idea of rupture; on the contrary, it stretches out towards a wider horizon that demands a rethinking of scientific knowledge in the context of a web of mutual relations between disciplines, discourses, and contexts. In this respect, the thought of Edgar Morin is particularly significant for its emphasis on the impossibility of

grasping scientific phenomena in a univocal and reductionist manner, and for its appeal to a complex way of thinking that is based on connection, dialogue, and recognition of complexity.

In this context, the need for a dialogical epistemology appears as a new philosophical horizon that overcomes the monological tendencies of traditional epistemology and reconstructs science as a communicative and participatory project open to the other. The question that arises is: Does contemporary science need this epistemological change? Can dialogical epistemology provide a philosophical answer that can grasp the complexity of scientific knowledge without falling into absolute relativism?

2. The Conceptual and Methodological Framework of Dialogical Epistemology:

2.1Defining Dialogical Epistemology:

In this article, dialogical epistemology is suggested as a cognitive approach that goes beyond the traditional understanding of epistemology as a descriptive and/or normatively closed theory of knowledge. Rather, it is understood as a cognitive approach that conceives the production of scientific knowledge as an interactive process based on a dialogue between different explanatory models and differentiated fields of knowledge, controlled by methodological reasons. However, this dialogue is not understood in general terms as linguistic communication and/or unregulated exchange of ideas, but rather as an epistemological practice informed by rigorous conceptual construction and/or clearly defined methodological constraints. As Edgar Morin underlines in his formulation of the dialogical principle in the epistemology of complexity, dialogical thinking does not consist in the elimination of contradiction, but in thinking together elements that are at the same time complementary and antagonistic (Morin, 1990, pp. 98-100).

Thus, the following operational definition of dialogical epistemology can be formulated: dialogical epistemology is an epistemological model that makes it possible to establish a systematic and methodologically organized dialogue between specialized scientific knowledge and other epistemic systems, while preserving conceptual consistency and scientific normativity. This model makes it possible to deal with complex problems that cannot be apprehended from the point of view of one discipline or one explanatory model alone. This definition is based on the following presuppositions: the plurality of methods and models does not, in itself, constitute an obstacle to knowledge; on the contrary, it may become a source of epistemic deepening, provided that it is organized within a framework of critical rational regulation (Bachelard, La formation de l'esprit scientifique, 1938, pp. 14-18). This is the sense of the rational regulation that Bachelard emphasizes, by which the construction of scientific concepts is a continuous practice of correcting illusions and errors.

In this sense, dialogical epistemology must be distinguished from those that tend towards a simple juxtaposition of perspectives, or those that, in the name of dialogue, lead towards epistemological relativism, and therefore to an impossibility of distinguishing scientifically productive knowledge from other types of discourse. Dialogue, in this sense, does not eliminate differences, nor does it seek a forced unity of methods, but rather establishes a rational organization of differences in a framework that makes it possible to critically relate them, transforming methodological tension into a productive feature of knowledge (Bachelard, L'activité rationaliste de la physique contemporaine, 1951, pp. 221-225).

In this sense, dialogical epistemology must not be understood as an alternative to scientific rationality, but rather as its reformulation in a complex and critical horizon, one that takes into account the historicity of scientific knowledge, the problematic nature of its conceptual construction, and the need to maintain a dialogue between models of explanation, without abandoning its requirements of precision, rigor, and normativity.

1.1.2 Distinguishing Dialogical Epistemology from Other Epistemological Models:

In order to establish the concept of dialogical epistemology and to determine the theoretical implications of this concept, it is necessary to distinguish dialogical epistemology from other epistemological models that have been the primary references of modern and contemporary scientific and philosophical thought. Dialogical epistemology does not appear in a theoretical void, nor does it manifest itself as a radical break with the epistemological tradition. On the contrary, it is based on a critical reaction to the limitations of these models and on an attempt to reorganize their relations in an epistemic framework that is more adequate to the complexity of contemporary scientific phenomena. (Morin, 1990, pp. 10-15).

In fact, the profound changes science has experienced at the level of its objects, methods, and schemes of explanation have shown the limitations of some classical epistemological theories with regard to the understanding of a reality in which the natural and the human, the quantitative and the qualitative, the experimental and the interpretive are increasingly interconnected. The classical epistemological theories, often organized around a logic of dichotomies and hierarchies between the different forms of knowledge, are not very successful in understanding this interdependence and this multidimensionality. It is in this sense that the proposal for a dialogical epistemology could be seen as an attempt to go beyond the logic of exclusion and domination that has structured the relationships between epistemological theories (Bachelard, La formation de l'esprit scientifique, 1938, pp. 27-35).

Consequently, the challenge of demarcating dialogical epistemology involves a critical assessment of the most prominent rival epistemological frameworks, not in order to reject them, but in an effort to better understand what makes dialogical epistemology distinctive in its understanding of scientific rationality, methodological pluralism, and epistemic difference as constitutive features of knowledge-creation. This critical assessment will thus be conducted through a step-by-step analysis of the three most influential approaches that have defined modern epistemological debates: positivist epistemology, pure hermeneutical epistemology, and epistemological relativism. These three approaches each emphasize a crucial aspect of scientific knowledge, but they also each expose inherent limitations that dialogical epistemology attempts to remove through a critically governed integration of plurality and rigor (Morin, La Méthode, 1977, pp. 38-45).

a. Positivist Epistemology:

Positivist epistemology has historically been one of the most important references in the construction of modern scientific rationality, especially in its emphasis on empirical observation, measurement, and the construction of general and verifiable laws. In this way, the emphasis on methodological unification and causal explanation was one of the most important aspects of the consolidation of rigor, predictability, and scientific knowledge, especially in the natural sciences. From this point of view, scientific knowledge is understood as a progressive accumulation of objective facts, unrelated to the knowing subject or exempt from any kind of historical or social contingency (Comte, 1830–1842, pp. 1-40).

However, the epistemological success of positivism was obtained at the price of a series of structural reductions. Positivist epistemology, in its linear causal approach and in its effort to isolate variables, often results in a fragmentation of complex realities and in the relegation of aspects that cannot be quantified, such as meaning, context, and reflexivity. This reductionist approach can be considered particularly dangerous when scientific practice is confronted with realities that present a multi-level organization and in which there is an interrelation between heterogeneous variables, as in the case of contemporary biology, social sciences, and cognitive science. Positivism thus demonstrates its limits not in relation to its methodological rigor, but in relation to its capacity for understanding the complexity of its own realities (Bachelard, La formation de l'esprit scientifique, 1938, pp. 27-35).

From the point of view of dialogical epistemology, therefore, positivism is neither rejected nor accepted, but critically re-elaborated as a moment of epistemology, like many others, whose positive aspects, such as precision, verification, and formal consistency, must be maintained, while its reductionism must be overcome. Dialogical epistemology aims at re-elaborating the rationality of

positivism within a more extended epistemological horizon, where empirical understanding is put into dialogue with other understandings, without any exclusive and epistemically privileged character, and therefore re-positioning it within a plural and regulated epistemology, rather than eliminating it or absolutizing it (Morin, La Méthode, 1977, pp. 38-45).

b- Pure Hermeneutical Epistemology:

Pure hermeneutical epistemology developed as a critical response to positivist reductionism, especially in its limitation of scientific knowledge to purely empirical observation and causal explanation. In its focus on understanding or Verstehen rather than explanation or Erklären, hermeneutics aimed to re-establish the primacy of meaning, historicity, and lived experiences in scientific knowledge of human and cultural phenomena. In this view, knowledge is not understood as a discovery of objective facts and laws, but as an interpretive process shaped within historical horizons and linguistic structures (Dilthey, 1910, pp. 225-245).

This shift of focus, which can be characterized as a 'hermeneutical turn,' played a decisive role in the subversion of the hegemony of positivist epistemology and in the legitimation of the specificity of the 'human sciences.' However, if taken to its extreme, pure 'hermeneutical epistemology' tends to undermine the criteria of scientific normativity. If knowledge is reduced to interpretation and contextual understanding alone, without any clear criteria of validation, then it is difficult to distinguish epistemically productive interpretations from arbitrary readings. In a sense, then, 'hermeneutical epistemology' risks leading to a kind of epistemological 'subjectivism' that undermines any possibility of critical evaluation and rational comparison of interpretations (Gadamer, 1960, pp. 295–307).

According to the dialogical epistemology perspective, the rejection of hermeneutics is impossible, at least to the extent to which hermeneutics emphasizes the importance of various aspects of understanding that cannot be ignored if we wish to grasp complex scientific and human phenomena. Yet, dialogical epistemology aims to combine hermeneutical understanding with a critically controlled epistemological framework, in which understanding is put into a dialogue with explanation, and meaning is articulated with regard to methodological rigor and rational control. In this way, dialogical epistemology overcomes both the reductionism of a positivistic approach and the relativism of a hermeneutical approach, transforming the opposition between explanation and understanding into a positive epistemological dialectic.

c- Epistemological Relativism:

Epistemological relativism was born as a powerful counter-critique to the universalistic and objectivistic pretensions of classical scientific rationality. Relativism strongly emphasized the historical and contextual character of knowledge. In relativistic epistemology, scientific knowledge is not seen as a reflection of objective reality, but rather as a result of certain paradigms, linguistic structures, and social-cultural practices that define what is a fact, an explanation, or a method. Relativistic epistemologies have contributed much to revealing the limits and constraints of absolutistic notions of truth and to showing the variety of epistemological traditions within the history of science. (Kuhn, 1962, pp. 92–110).

This critical contribution, however, takes an epistemologically problematic turn when the radicalization of relativism leads to a denial of any common criteria of rational evaluation. If scientific paradigms are considered incommensurable worldviews without any common ground for rational evaluation, then any possibility of rational dialogue between different scientific theories is ruled out. In such a case, scientific development would appear to have a sociological or rhetorical nature rather than an epistemological one. This problem is particularly evident in extreme versions of relativism that consider scientific rationality to be dissolved into a multiplicity of equally valid (Feyerabend, 1975, pp. 27–45).

From the perspective of dialogical epistemology, the problem of epistemological relativism is not the problem of plurality per se but the problem of epistemic fragmentation that arises from the abandonment of critical normativity. Dialogical epistemology aims to retain the relativist insight into the historicity and diversity of knowledge while rejecting the conclusion that all epistemic frameworks are incommensurable and of equal validity. Rather, it offers a critically regulated dialogue in which various models of knowledge can be compared, assessed, and formulated without being reduced to a unified paradigm or falling apart into relativistic fragmentation. In this respect, dialogical epistemology turns the relativist critique into a productive moment within a rational and plural epistemological horizon.

d) Dialogical Epistemology as a Synthetic Horizon:

In contrast to the epistemological models considered in the previous sections, the dialogical epistemology postulates a synthetic horizon that is not supported by exclusion or substitution, but by the restructuring of the relationships between the different epistemological models in a critical rational framework. This epistemology does not refute the methodological rigor that the epistemology of positivism attained, nor the hermeneutic focus on meaning and context, nor the relativist focus on

the historicity and diversity of knowledge. Instead, it tries to go beyond the limitations of each of these models by placing them in a regulated dialogical framework.

This synthetic horizon is founded on the assumption that the plurality of methods, as such, is not a threat to the unification of knowledge, but may become a source of epistemological enrichment, provided it is submitted to a critical rational regulation of the conditions and boundaries of the dialogue. In this sense, the idea of the dialogue is not to favor the eclectic and unifying use of the methods, but to create the epistemological space in which the models are able to interact, transforming the tensions between them into a resource of creative reconstruction and development.

Hence, dialogical epistemology is characterized by a dynamic understanding of scientific rationality, one that recognizes the existence of several planes of explanation and the problematic nature of knowledge construction, without renouncing the need for precision and normativity. Dialogical epistemology does not offer itself as a counter-position to scientific rationality, but rather as a reformulation of it in a complex reality that combines openness and regulation, and plurality and criticality, in order to produce a dialogue that is effectively epistemological.

2.2Drivers of Dialogical Epistemology:

The need for the development of dialogical epistemology is fueled by the deep transformations that have impacted the knowledge of the objects of science, the methods of science, and the explanatory practices of science. These transformations have made the linear, unidisciplinary, and certainty-oriented models of classical epistemology obsolete. In such a context, dialogical epistemology is not presented as a theoretical option among others, but rather as an epistemological necessity resulting from the internal dynamics of the evolution of science itself (Morin, Introduction à la pensée complexe, 1990, pp. 12–18).

The first crucial motivator for dialogical epistemology arises from a movement away from linear explanation toward complex modeling. Modern science is faced with a large number of phenomena that exhibit non-linearity, feedback, and multi-levelness, with causes and effects becoming deeply intertwined within a system that is constantly evolving. These kinds of phenomena cannot be understood in terms of linear cause-effect relationships or in terms of variables that operate in isolation from each other. Complex modeling is required to integrate a variety of heterogeneous factors, which in their turn require different levels of explanation. (Morin, La Méthode, 1977, pp. 101–115).

Another major driver is the rise of interdisciplinarity as a structural feature of scientific research in contemporary society. Global challenges like climate change, public health crises, artificial intelligence, and ecological degradation require the cooperation of the natural sciences, social sciences, and humanities, as they go beyond the scope of individual scientific disciplines. However, interdisciplinarity is not merely a juxtaposition of disciplinary approaches, as it requires an epistemological basis that would allow for the organization of interdisciplinarity, the specification of each discipline's scope, and the regulation of their interplay. Dialogical epistemology meets this need by offering a rational space where disciplinary differences are articulated, as opposed to being dissolved (Klein, 1990, pp. 55–72).

The third factor relates to the change in the epistemic status of uncertainty, probability, and contradiction itself. The advances in quantum physics, complexity science, and systems biology have demonstrated that uncertainty is not just a temporary condition of ignorance to be overcome, but rather a structural feature of scientific inquiry. Uncertainty does not threaten rationality but rather triggers the improvement of models, the restatement of problems, and the enhancement of dialogue between rival approaches. In this view, dialogical epistemology subsumes uncertainty into a critically governed process of knowledge production, turning it from a deficit into a productive resource. (Prigogine, 1997, pp. 3–15).

2.3 Limits of Traditional Epistemological Models:

The limitations of the classical epistemological models are particularly apparent when faced with the complexity, instability, and multi-dimensionality inherent in the current state of the science. The classical epistemology, built on the principles of linear causality, methodological unification, and disciplinary rigidity, appears not sufficient for the understanding of the complex phenomena characterized by interaction and non-equilibrium. This does not mean that the classical epistemological achievements are not worthy; it means, however, that the classical epistemology must be reassessed in the context of the current state of the science (Morin, Introduction à la pensée complexe, 1990, pp. 22–30).

The first limitation is based on the reductionist approach, which aims to describe complex phenomena by reducing them to simple constituents or linear causal chains. This type of approach neglects the systemic and interactive aspects of a phenomenon and fails to take into account the emergent properties that cannot be derived simply from the sum of the parts. In this respect, reductionism represents an epistemological barrier to understanding the dynamic complexity that typifies many modern scientific objects.

The second major limitation of classical epistemology lies in the strict separation, traditionally maintained, between the knowing subject and the known object. In fact, classical epistemology has implicitly assumed the possibility of a kind of observer, at once neutral and detached, able to gain access to an objective reality, whatever the historical, social, and cognitive conditions may be. However, recent developments in the philosophy and sociology of science have shown that scientific knowledge is always constructed within particular theoretical, technical, and institutional conditions. The knowing subject is therefore not external to the process of producing scientific knowledge, as it is actively involved in the construction, interpretation, and validation of scientific models. The subject-object dichotomy therefore tends to conceal the reflexive and constructive aspects of scientific activity (Kuhn, 1962, pp. 121–135).

A third limitation is the absence of methodological tools that are capable of addressing the complexity and uncertainty of scientific knowledge. The classical models, which assume stability and certainty, are found wanting when it comes to addressing phenomena that are characterized by non-equilibrium, probability, and change. This has resulted in the development of new epistemological tools that are capable of addressing uncertainty and diversity within a rational and regulated process of knowledge, a requirement that is fulfilled by dialogical epistemology.

3.Edgar Morin and the Epistemology of Complexity:

3.1Complexity and System:

Epistemology of complexity developed by Edgar Morin represents a radical change in the concept of scientific knowledge to the extent to which it overcomes the reductionist and simplifying trends of classical epistemology. Complexity, for Morin, does not mean confusion, disorder, or a sum of difficulties, but the organized interrelation of heterogeneous elements within an open system. The phenomenon is not seen as complex because it is unclear, but because it cannot be made clear through the isolation of its constituent parts without taking into consideration the set of relations between them (Morin, La Méthode, 1977, pp. 100–108).

From this point of view, complexity does not refer to the absence of order, but rather to the presence and coexistence of order and disorder, stability and dynamism, within the same structure. In this way, the notion of the system appears to be a fundamental element in the construction of the epistemology proposed by Morin, insofar as it allows for an understanding of the phenomenon as a whole, without reducing it to its mere parts. In this sense, an open system can be defined as a system capable of interacting with its environment and exchanging matter, energy, and information, thus maintaining a state of continuous formation.

From this systemic perspective, there appears to be a break from an analytical approach that rigorously separates the various levels of reality, in favor of a synthetic perspective capable of integrating physical, biological, social, and human aspects. In this sense, the notion of complexity proposed by Morin provides an epistemological perspective in which the possibility of a dialogue between diverse forms of knowledge can be established without falling into any form of reductionism or simplistic holism. In this sense, the epistemology of complexity can be considered a fundamental theoretical foundation for a dialogical epistemology.

.32.Principles of Complex Thought: From Complexity to a Dialogical Epistemological Horizon:

Morin does not see complex thought as a closed methodological system or as a set of technical procedures that can be applied in a mechanical way. Complex thought is an epistemological approach whose goal is to transform the act of knowing itself, in response to the increasing complexity of scientific and human realities. The principles of complex thought are seen as dynamic conceptual operators in rational thought, avoiding reductionism and simplification without losing intelligibility and organization (Morin, Introduction à la pensée complexe, 1990, pp. 67–72).

a) The Dialogic Principle: Contradiction as a Condition of Knowledge:

The dialogic principle is one of the essential foundations of Morin's epistemology of complexity. This principle states that contradiction is not an epistemological or logical defect to be eliminated from thought, but an essential component of knowledge. Complex thought does not try to overcome contradictions by suppressing or synthesizing them. Complex thought aspires to think simultaneously the complementary and antagonist aspects of a situation, such as order and disorder, stability and instability, unity and plurality. This principle of complexity allows for a logic of conjunction (both/and), instead of a logic of exclusion (either/or), which can explain the contradictions of complex realities (Morin, La Méthode, 1977, pp. 240–248).

b) The Principle of Recursivity: Beyond Linear Causality:

The idea of recursivity contests the linear model of causality that has long been the basis for classical scientific explanation. In recursive systems, the consequences of a process not only result from their causes but also return to the very conditions that brought them into being. Causes and effects enter into circular relations in which products play a part in the reproduction, regulation, or transformation of the system itself. This logic of recursivity is especially apparent in living, social, and cognitive systems, in which organization arises from the endless interactions between structure and process. With the introduction of the idea of recursivity, Morin underlines the fact that scientific knowledge

must take into account feedback, self-organization, and historical transformation instead of being based on linear determinism (Morin, La Méthode, 1977, pp. 198-205).

c) The Hologrammatic Principle: Overcoming the Whole/Part Dichotomy:

The hologrammatic principle states a non-reductionist view of the relationship between the whole and its parts. The principle asserts that the part is contained in the whole, as the whole is defined by the interactions of its parts. In a complex system, no element can be comprehended in itself, but the whole lacks existence apart from its elements. The hologrammatic principle enables complex thinking to reconcile the opposition between holistic and atomistic perspectives by stating the implication of levels of organization. From an epistemological point of view, it enables the integration of the biological, social, and human aspects of knowledge without losing their specificity (Morin, Introduction à la pensée complexe, 1990, pp. 101-108).

Through such principles, complex thought aims to rebuild scientific rationality in an open and reflexive space in which the presence of plurality, contradiction, and incompleteness is recognized as essential characteristics of knowledge. Far from undermining scientific rationality, such principles strengthen its capacity for knowledge of complex realities, transforming tension, uncertainty, and diversity into epistemological assets. In this way, Morin's principles of complex thought can be seen to offer a basic epistemological support for dialogical epistemology, while also revealing the necessity for critical regulation, in order to avoid the risk of vagueness and holism or relativism (Morin, La Méthode. Tome 6 : Éthique, 2008, pp. 32-40)

d) From the Principles of Complexity to Dialogical Epistemology:

The epistemological relevance of Morin's principles of complex thought is not only to be found in their explanatory capacity concerning complex phenomena, but also in their potential for underpinning a dialogical epistemology. This is founded on methodological pluralism, conceptual flexibility, and the recognition of uncertainty as a productive force of knowledge.

Nevertheless, despite its fecundity, this horizon is vulnerable to the risk of lapsing into epistemological relativism or diffuse holism if it is not sustained by a rigorous framework of critical rationality. It is exactly at this point that the importance of Gaston Bachelard's epistemological rationalism becomes pertinent. By means of his ideas of epistemological rupture, concept-formation, and normative rationality, Bachelard furnishes the critical instruments required to underpin methodological rigor in any dialogical epistemology. The analysis of this rational corrective will be the concern of the next section.

3.4The Limits of Morin's Perspective: Between the Horizon of Complexity and the Need for Epistemological Regulation:

Notwithstanding the obvious theoretical richness of Edgar Morin's epistemology of complexity and the new possibilities it opens up for understanding modern science and complex human phenomena, this approach is not, however, without its epistemological boundaries. These boundaries do not call into question the relevance of Morin's achievement, but rather the need to critically assess the conditions under which complexity can continue to be a fruitful epistemological approach. Without clear criteria of epistemological regulation, complexity may well be reduced from a critical approach to thought to a discourse that is too inclusive, in which the boundary between fruitful diversity and conceptual diffusion becomes increasingly difficult to distinguish (Morin, Introduction à la pensée complexe, 1990, pp. 135-142).

One of the major risks of the epistemology of complexity is its potential for epistemological holism. If the dialogical principle is carried out in such a way that there are no methodological limitations, then the distinction between different domains of knowledge may lose its clear contours; in such a case, all forms of discourse may appear equally legitimate from an epistemic point of view. Although Morin's emphasis on the need for openness to plurality and interdisciplinarity is well-founded, the lack of clear criteria for differentiation and evaluation may lead to an unjustified leveling of epistemic practices that are fundamentally different in terms of their structures, methods, and conditions of validity; in such a case, the openness of the dialogical principle may lead to epistemological relativism in which the value of plurality can no longer be seen as enriching but rather dissolving the normativity of epistemic statements (Morin, La Méthode, 1977, pp. 300-310).

Another limitation to be noted is the nature of some of the key notions employed by Morin, such as system, organization, interaction, and emergence. These notions have a strong synthetic and heuristic potential, which enables the articulation of heterogeneous aspects of reality. However, if these notions are not accompanied by the specification of the mechanisms of their conceptual construction and validation, they may remain at the level of philosophical orientations rather than being rigorously operational epistemological tools. The danger here is not the ambiguity of the notions themselves but the blurring of the criteria that make science distinct from any other form of explanation (Morin, La Méthode. Tome 6 : Éthique, 2008, pp. 48-56).

According to this view, the full epistemological potential of complexity will only be realized if it is articulated with a form of critical rationality that is capable of regulating conceptual construction, guaranteeing epistemological rupture with naïve representation, and specifying the conditions of

scientific validity. Morin's thought, as rich as it is, also invites an epistemological complementarity rather than self-sufficiency. It is precisely at this point that the critical rationalism of Gaston Bachelard appears as a determining corrective, capable of accompanying the epistemology of complexity without draining it of its openness, and of regulating dialogical plurality without exhausting it. This requirement of regulation will be the point of departure for the transition from the epistemology of complexity to critical rationality, as elaborated by Bachelard, which will be analyzed in the following section.

4.Gaston Bachelard and Critical Rationalism:

4.1Epistemological Rupture: From Obstacles to Knowledge to Building Scientific Concepts:

The epistemological rupture forms the core of Gaston Bachelard's critical rationalism and one of the most important legacies in the philosophy of science of the twentieth century. While the classical view of scientific knowledge follows the idea of its cumulative and continuous development from facts, Bachelard's philosophy of science emphasizes the discontinuous nature of scientific progress through ruptures in the preceding forms of thinking. In other words, scientific knowledge is not formed through the refinement of common sense or immediate experience but through ruptures with common sense or immediate experience itself. In this respect, scientific progress is achieved through a rational fight against what Bachelard famously called epistemological obstacles, i.e., spontaneous representations of the world, images, or thinking that oppose the formation of scientific concepts (Bachelard, La formation de l'esprit scientifique, 1938, pp. 13-24).

However, epistemological rupture is not merely a historical, nor a psychological, phenomenon, but a rational one as well, as it involves a critical transformation of the relation between reason and reality, where the latter is no longer considered immediately given, but constructed through a mediation of theory and experiment. In Bachelard's view, scientific knowledge is grounded on a problem, and not on observation, and the scientific object is a result of a rational construction. What is "obvious," as seen from a common-sense point of view, is, from an epistemological point of view, a barrier that must be overcome through rational criticism and methodological vigilance (Bachelard, La formation de l'esprit scientifique, 1938, pp. 25-34).

In this approach, epistemological break has a positive and productive role. Through the break with naive realism and pre-scientific representation, scientific reason liberates itself from the illusion of immediacy and attains access to higher levels of intelligibility. Scientific concepts are not mirrors of reality but tools for structuring experience and creating new levels of intelligibility. This understanding radically transforms scientific rationality into a dynamic, historical, and self-correcting

process, instead of a passive reflection of an objective reality (Bachelard, La formation de l'esprit scientifique, 1938, pp. 35-44).

The current relevance of epistemological rupture may be grasped particularly if we consider it in the context of the epistemology of complexity. While dialogical openness and methodological plurality cannot be disregarded in the treatment of complex phenomena, we may also learn from Bachelard's epistemology that this openness will be epistemologically fruitful only if underpinned by critical criteria. In this way, epistemological rupture appears as a prerequisite of any dialogical epistemology that seeks to avoid the risks of relativism and conceptual vagueness, so that the dialogue remains a rational and fruitful process, rather than a juxtaposition of heterogeneous discourses.

4.2Applied Rationality: The Dialectic of Theory and Experiment and the Construction of Scientific Normativity:

Applied rationality is the heart of Gaston Bachelard's critical rationalism. It represents the notion that scientific rationality is not merely an abstract logical structure or a reflection of empirical facts, but rather a process that is based on the dialectical relationship between theory and experiment. In opposition to naive empiricism, which holds that knowledge is based on observation, and in opposition to formal rationalism, which abstracts concepts from their experimental contexts, Bachelard contends that scientific knowledge can only be achieved through a constant oscillation between conceptual construction and experimental validation (Bachelard, Le rationalisme appliqué, 1949, pp. 7-15).

Bachelard criticizes naive empiricism, which considers experience the starting point of knowledge, and at the same time rejects formal rationalism, which abstracts concepts from the context of their empirical implementation. Scientific experimentation, according to Bachelard, is not an immediate experience but a prepared activity within a determinate theoretical horizon. This explains why he says that "experience is not given, it is constructed," and that scientific facts are known only as answers to theoretically formulated questions.

Moreover, applied rationality involves a redefinition of scientific normativity. According to Bachelard, scientific norms are neither imposed from outside of knowledge, nor do they result from the postulated correspondence between knowledge and reality. On the contrary, scientific normativity is immanent within scientific practice and is based on the fecundity, coherence, and rectifiability of scientific concepts. In other words, a scientific concept is considered scientifically valid, not because it corresponds to reality, but because it proves to be fertile, coherent, and rectifiable in scientific

practice. Scientific rationality is therefore self-corrective and historical, as Bachelard argued (Bachelard, Le rationalisme appliqué, 1949, pp. 45-56).

The epistemological interest of applied rationality resides first and foremost in its capacity to produce scientific normativity without falling into dogmatism. Indeed, for Bachelard, scientific norms cannot be justified by the simple relationship between thought and reality, but rather by the fecundity of scientific concepts, i.e., their capacity to organize, explain, and predict, as well as their capacity for refutation from within scientific practice itself. Applied rationality thus appears as a regulative internal process, rather than as an external authority.

Within the framework of this article, applied rationality becomes a crucial factor in that it offers the framework within which methodological pluralism and epistemic dialogue can be combined without losing rigor. It makes dialogue between scientific models a fruitful confrontation rather than a random juxtaposition, and avoids the risk of epistemic openness lapsing into unregulated relativism. In this regard, Bachelard's applied rationality is a necessary condition for any dialogical epistemology that aims to combine openness with regulation, complexity with normativity.

4.3Rational Pluralism and Dialogue Within Science:

On the contrary, whereas the common perception of Gaston Bachelard's philosophical work is that of a radical and unyielding rationalism, if one looks more closely at his theory of knowledge, it can be seen that there is a complex and nuanced understanding of the nature of scientific rationality in terms of pluralism. For Bachelard, the history of science does not develop in accordance with a single and homogeneous rationality, but with the coexistence and interaction of multiple rationalities, each of which is related to specific domains and specific levels of abstraction and conceptual construction. Scientific rationality is inherently differentiated, historical, and dynamic.

This pluralism, however, should not be confused with epistemological relativism. Bachelard argues that this plurality of rationalities in science does not imply that they are equivalent or that they coexist in an arbitrary fashion. Instead, each rationality is tested through rigorous criteria of validation and experimentation. Scientific dialogue is not just an exchange of points of view but a rigorous confrontation of theories that are tested and sometimes refuted. Contradiction in science thus becomes a driving force for conceptual and epistemological development rather than undermining rationality (Bachelard, L'activité rationaliste de la physique contemporaine, 1951, pp. 210-218).

From this perspective, scientific dialogue has a strictly epistemological sense. It is not founded upon tolerance, nor upon the awareness of diversity, but upon epistemological responsibility. Scientific

dialogue between models is fruitful only to the extent that it is subject to critical regulations allowing for differentiation between fruitful and non-fruitful dialogues. This perspective places Bachelard closer to Morin's critique of reductionist monism, but also sets him apart through the emphasis upon methodological rigor. Rational pluralism cannot be thought of without critical regulation (Bachelard, L'activité rationaliste de la physique contemporaine, 1951, pp. 219-229).

In this sense, Bachelard agrees with Morin in his opposition to exclusivist monism, but disagrees with him in terms of the extent to which normative regulation is emphasized. Bachelard's dialogue is not based merely upon openness, but upon epistemological responsibility, which distinguishes fertile approaches from those which are not scientifically rigorous. Bachelardian rational pluralism can thus be seen as a regulative model of scientific dialogue, which permits the coexistence of various scientific methods without falling into relativism and epistemological disintegration.

This conception shows that Bachelard is not in opposition to dialogical epistemology, but rather one of its conditions of possibility: namely, the passage from dialogue as the simple encounter of differences to a critical rational practice capable of producing a deeper and more precise knowledge. Rational pluralism thus appears as a structural element of any epistemological project aiming at the reconciliation of complexity, diversity, and scientific rigor.

4.4The Contemporary Relevance of Bachelard in the Context of Modern Science:

The reason for the relevance of Gaston Bachelard's epistemology today is not simply because of its historical importance within the development of twentieth-century philosophy of science, but also because of its ability to throw light upon the epistemological issues raised by the practice of science today. The science of today is increasingly characterized by abstraction, modeling, probability, and instrumentation. In such a context, Bachelard's emphasis on the constructed nature of science is a strong corrective to naive realism and the assumption of immediate access to reality (Bachelard, La formation de l'esprit scientifique, 1938, pp. 247-255).

The advances in fields like quantum physics, molecular biology, neuroscience, and cognitive science support Bachelard's argument about the nature of scientific facts: "The facts are not immediate data; they are the fruit of a complex construction. Scientific objects are constructed with a set of hypotheses, formalizations, and devices. This supports Bachelard's argument about the nature of rationality: it is not a matter of the transparency between the observed and reality, but rather a matter of abstraction and the rectification of concepts" (Bachelard, 1949, 87-96).

The concepts of epistemological obstacle and epistemological rupture also seem to be relevant in an era characterized by the acceleration of knowledge production, as well as the close connection of scientific knowledge with the media, technology, and ideology. In the current scientific discourse, immediacy and simplification are often present, which may obscure the complexity of conceptual construction, especially in fields like artificial intelligence, genetics, or data science. In this respect, the epistemology of Bachelard may be useful in distinguishing scientific explanation from representation, as well as knowledge from social obviousness (Bachelard, 1938, pp. 19-27).

In terms of dialogical epistemology, the contemporary relevance of Bachelard consists precisely in his capacity to manage epistemic openness without stifling it. The critical rationalism of Bachelard is thus not geared towards stifling scientific dialogue, but towards making it more rigorous and productive by providing it with criteria of evaluation and conceptual discipline. It is thus in this way that Bachelard seems less as an adversary of complexity and dialogue, and more as an epistemological complement that makes dialogical epistemology less relativistic and more capable of engaging complexity in modern science.5. Epistemological Synthesis: A Dialogue between Morin and Bachelard:

5.1 The Possibilities of Epistemological Synthesis: From Complexity to Critical Rationality:

The possibility of an epistemological synthesis between Edgar Morin and Gaston Bachelard cannot be thought of in the form of a reconciliation between two heterogeneous perspectives, nor in the form of a search for a common denominator, which would allow for the cancellation of the tensions specific to each perspective. On the contrary, it is based on the awareness of the fact that, in contemporary scientific knowledge, one must be open to complexity and epistemological regulation. The relevance of such a synthesis is determined by the limits of each perspective when considered separately (Morin, Introduction à la pensée complexe, 1990, pp. 131-138).

Morin's epistemology of complexity gives us access to the conceptual framework that allows us to understand the interdependence of scientific phenomena, the diversity of models of explanation, and the non-linear nature of scientific knowledge. The emphasis on dialogical relations, interaction of systems, and uncertainty allows us to understand science as an open and dynamic process. However, this openness, if it is not accompanied by explicit criteria of epistemological control, can provoke a weakening of scientific normativity and create problems of distinguishing between epistemologically productive dialogue and juxtaposition of different points of view (Morin, La Méthode, 1977, pp. 300–308).

In contrast, Bachelard's critical rationalism provides the epistemological tools necessary to control this openness. By the notions of epistemological rupture, applied rationality, and rational pluralism, Bachelard emphasizes the need for conceptual building, methodological caution, and internal regulation in scientific practice. Scientific knowledge, for Bachelard, proceeds by critical interruptions of naive representations and by the controlled reconstruction of concepts in light of experimental and theoretical constraints. However, when considered in isolation from a systemic and dialogical framework, this rationalism tends to be too compartmentalized, too oblivious to the interconnections of modern scientific objects (Bachelard, Le rationalisme appliqué, 1949, pp. 97-105).

From this point of view, dialogical epistemology thus appears as a critically regulated space in which different models of explanation can meet without losing their specificity or normative foundation. The synthesis between Morin's and Bachelard's thought thus makes it possible to think of scientific knowledge as a rational practice that is at once open and disciplined, plural and critical, historical and normatively structured. This synthesis thus provides the conceptual ground upon which the dialogical epistemology suggested here is constructed

5.2.Key Features of the Proposed Dialogical Epistemology:

Based on the epistemological synthesis that can be obtained between the epistemology of complexity developed by Edgar Morin and the critical rationalism of Gaston Bachelard, it is possible to define the main characteristics of a dialogical epistemology that transcends the idea of openness and/or methodological pluralism in a general way. The model that has been proposed does not pretend either to transcend the differences between the frameworks of knowledge, nor to impose a unifying meta-theory, but rather to organize the plurality in a critically regulated epistemological space (Morin, Introduction à la pensée complexe, 1990, pp. 139-145).

The first important feature of dialogical epistemology is the constitution of a critically regulated systemic dialogue. The dialogue is not understood as an unregulated communication between heterogeneous approaches, but as a regulated communication that is guided by norms that determine the degree and scope of validity of the different discourses. The regulated character of the dialogue aims at ensuring that the diversity of methods does not bring about fragmentation, but that it actually contributes to epistemological enrichment through rational confrontation and criticism. In this sense, dialogue is not only an ideal of communication, but it is actually a regulated epistemological practice (Bachelard, Le rationalisme appliqué, 1949, pp. 106–115).

The second crucial aspect is found in the acknowledgment of methodological pluralism as an epistemological virtue. Dialogical epistemology recognizes the fact that complex phenomena cannot be grasped satisfactorily by a single explanatory paradigm or by a disciplinary approach. Nevertheless, this pluralism is not to be considered a relativistic concession. Instead, it is submitted to a critical rational assessment, which enables the distinction between epistemically productive approaches and those that are deficient in explanatory or conceptual stringency. Plurality is no longer a cause of epistemic diffusion but of epistemic deepening (Morin, La Méthode, 1977, pp. 310-318).

The third characteristic involves the transformation of the relationship between scientific knowledge, human values, and contexts. Within this dialogical epistemology, scientific knowledge is no longer seen as an autonomous and self-sufficient practice separate from its own historical and social contexts. However, this contextualization of scientific knowledge does not mean that scientific rationality is subordinated to external factors. Instead, contexts are reflected upon in scientific knowledge itself in such a way that science can be both contextual and epistemologically rigorous (Bachelard, L'activité rationaliste de la physique contemporaine, 1951, pp. 305-312).

Finally, the epistemology of dialogue rests on the assumption of uncertainty and incompleteness as structural features of current scientific knowledge. Uncertainty will not be seen as a problem to be solved once and for all, but as a resource for the construction of models, the reformulation of problems, and the strengthening of dialogue between different approaches. Thus, the epistemology of dialogue appears as a promising framework for the integration of openness and regulation, plurality and normativity, into a unitary and coherent scientific practice (Morin, La Méthode. Tome 6 : Éthique, 2008, pp. 41-48).

5.3.Potential Applications of Dialogical Epistemology:

This dialogical epistemology is not only a project for a theoretical reconstruction of scientific rationality but also one with specific methodological and practical implications for contemporary scientific research. The value and significance of this epistemology become particularly clear with regard to sciences that deal with complex objects, multi-level causality, and interdependencies among natural, social, and human dimensions. In this case, dialogical epistemology is a perspective that is able to synthesize different types of knowledge without losing its epistemological strength (Morin, Introduction à la pensée complexe, 1990, pp. 146-152).

One of the most important areas where dialogical epistemology can be applied is that of interdisciplinary and transdisciplinary research. Disciplines such as life sciences, sociology, cognitive sciences, and environmental sciences study phenomena that cannot be understood at one level.

Biological processes, for example, cannot be understood outside their ecological, social, and cultural contexts, any more than cognitive processes can be understood outside neurological, psychological, and social contexts. In dialogical epistemology, these levels can be connected through a controlled interaction between models, thus avoiding any reductionism and vague holism (Morin, La Méthode, 1977, pp. 320-330).

The second significant area of application is that of research ethics and scientific decision-making. Modern scientific practices often have ethical, political, and social implications, as is seen with regard to climate change, genetic engineering, or artificial intelligence, to name a few. In these contexts, scientific expertise is not sufficient, nor can ethical or political considerations be privileged over scientific rationality. Dialogical epistemology is a model in which different kinds of expertise, whether scientific, ethical, or legal, can be brought into a critically controlled dialogue, so that decisions are socially responsible as well as epistemologically well-founded (Bachelard, L'activité rationaliste de la physique contemporaine, 1951, pp. 312-320).

Dialogical epistemology has also significant implications for research methodological strategies and construction of models. In fact, the acknowledgment of uncertainty, incompleteness, and contradiction in knowledge production stimulates the development of multi-level analytical models capable of adjusting to changing phenomena. Thus, instead of looking for absolute forms of explanation, dialogical epistemology promotes iterative modeling of phenomena, constant refinement of hypotheses, and confrontation between different explanatory strategies in a rationally controlled manner. This approach is particularly relevant in the current scientific world characterized by constant change and innovation (Prigogine, 1997, pp. 29-38).

Lastly, the educational and institutional aspects of scientific practice represent another domain in which dialogical epistemology could potentially have an impact of major transformative importance. Indeed, in higher education and training in scientific research, the rigid distinction between disciplines can at times impede the ability of scientists to deal with complex issues. Through the promotion of dialogical competencies and critical epistemological awareness, dialogical epistemology can help build scientists who are capable of dealing with plurality without sacrificing rigor, and capable of working in an interdisciplinary context without dissolving their own disciplines (Klein, 1990, pp. 85–98).

6. Conclusion:

This paper has aimed to analyze the epistemological basis of modern science in the context of increasing complexity, proliferation of models, and the role of uncertainty and probability. In reaction

to these changes, it has proposed an epistemological framework that is dialogical and able to meet the challenges of modern science without being reductionist or relativistic. This has been done through a critical synthesis of the epistemology of complexity of Edgar Morin and the critical rationalism of Gaston Bachelard, as complementary rather than antagonistic approaches.

As has been demonstrated in the course of this analysis, the epistemology of complexity can expand the horizon of scientific knowledge by integrating plurality, contradiction, and completeness, and by encouraging dialogue between disciplines and epistemic systems. However, such an openness, however necessary it may be, can easily be threatened by losing its normativity without being complemented by a critical rationality. In this context, Bachelardian epistemology offers invaluable instruments of epistemological rupture, conceptual construction, and methodological rigor that can regulate epistemic dialogue without closing it.

The article has also shown that the proposed model of dialogical epistemology is not just a conciliatory attitude, but rather a consistent epistemological model based on critically regulated systemic dialogue, normative methodological pluralism, and the recognition of uncertainty as a creative dimension of scientific knowledge. By its possible applications in interdisciplinary sciences, research ethics, and scientific methodology, the proposed model shows its capacity for contributing to a better understanding of the key challenges in science and society.

From this perspective, the article can be seen to make a contribution to current epistemological debates in affirming the possibility of reconciling openness and regulation, complexity and rigor, in one and the same responsible scientific practice. At the same time, it can be seen to open up perspectives for future research on dialogical epistemology in science policy, in the field of higher education, or in research design, thus reinforcing the importance of philosophy in accompanying and guiding the evolution of scientific knowledge.

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