SCIENCE OF COMPLEXITY AND THE METHODOLOGICAL PROBLEMS RAISED

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ABSTRACT

The article generally introduces the history and role of science of complexity in contemporary scientific research, and then raises methodological problems regarding science of complexity. From the standpoint of marxist methodology, the article comes to make initial related comments.

Since the 90s of the XX century, science has made considerable progress in the far-reaching and going into the physical world, giving mankind the new awareness, and posing new problems in terms of methodology, of which, notably the emergence and spreading development of complex science (science of complexity). In this article, we present an overview of this field of science and raise methodological issues thereby.

According to the common understanding, modern science rooted in the era of Enlightenment in the seventeenth century, beginning with the discovery of Kepler[2], Galileio[3] and Newton[4] of the laws of physical motion. Besides, practically, the industrial revolution has created a strong leverage for the development of science. The emergence of science has created a huge turning point in the history of human civilization. It was the first time for man to find a way to perceive the world by his power of "mundane" thinking and reasoning, which was previously only a desire to be clamped together by chains of religion. Since then, science has continued to grow strongly in areas of research on nature such as mechanics, physics, astronomy,.etc... Accordingly, the scientific method is proposed and perfected on the mechanistic thinking[5] by Newton and Descartes, Laplace's[6] determinism, mathematical calculus (Newton and Leibniz), and logical analogy of form. Thanks to the scientific methods, people have built up the mathematical model consistent with physical reality correctly, so that scientific knowledge is produced as it is true about the natural world.

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[2] *Johannes Kepler (1571 - 1630), a German, an important face in the scientific revolution. He is famous for the laws of planetary motion through the astronomy projects such as new (Astronomia nova), world harmony (Harmonice Mundi) and textbook Summary of Copernican astronomy.*

[3] *Galileo Galilei (1564 - 1642), an Italian astronomer, physicist, mathematician and philosopher, who played a key role in the scientific revolution. His achievements include improvements to the telescopes and other astronomical observations. Galileo is considered the "father of the observations of modern astronomy", the "father of modern physics", and "father of modern science."*

[4] *Isaac Newton (1642 - 1727), a British physicist, astronomer, philosopher, mathematician, theologian and alchemist. His greatest work "Philosophiae Naturalis Principia Mathematica (The Mathematical Principles of Natural Philosophy) considered the foundation of classical mechanics, has dominated the conception of physical science during the 3 next century.*

[5] *The objects, phenomena and processes in the world are machines.*

[6] *According to Laplace, at a certain point, if we know the position and velocity of all objects in the universe, we can calculate their status at any time in the past and future.*

From the mid-nineteenth to the twentieth century, the scientific methods were deployed more in the research areas of life, economics, politics, society, literature, poetry, art, with ideas of those existing rules governing human society similar to laws dominating the physical world, the nature. For example in the field of economics, many economic theories have a bold impact on economic development and human society throughout the past century. For a bit more convincing, more theories of society and humanity have applied the scientific methods. Overall, the spirit of science is that the objects always contain attributes such as balance, stability, symmetry, deterministic, and linear. The strong development of sophisticated, modern research technology enables us to deepen, expand, reach out, penetrate deeper into the endless vast world of material. Consequently, from the late XX to XXI century, science has in turn made many new areas of research, which highlights the complex science.

Complex science is the science of complex systems. A system is said to be complex if it contains elements interacting with one another, to show the nature and the behavior which can not be obviously figured out from the interaction of the components. Scientists have long had difficulty studying the phase transition, such as the phenomenon of boiling water, in particular, and in general the systems containing many elements, or components. Today science has created many effective tools such as thermodynamics, statistical mechanics to study the system in equilibrium. The equilibrium systems are not completely complex systems. However, the study of equilibrium systems will create more favorable conditions for the study of complex systems through their concepts and ideas.

Upon the current knowledge, the dynamical systems are out of equilibrium state, and nonlinear which are important in the universe. We may indicate some common complex systems, for example, economic system, the stock market system, climate system, social system of organisms, seismic system, transport system, information system, environment system, system of swirling flow, system of diseases, immune system, dynamic river system, geological system, the system of pigmentation on animal fur, the circulatory system of the heart, the genetic system, and so on.

The characteristic to be considered most important in complex systems is the phenomenon of sudden birth (emergence). It is a phenomenon that produces the laws, forms, new order from the collective effects of the interactions between the components of the system. Especially, the emergence is not an intrinsic property of the components, that is the nature of the system to be viewed globally. For example, temperature, and the laws of gases – these concepts are meaningless if we only consider a molecule, which only has a meaning for a system of molecules. Or, an organization of ant populations, each ant only acts according to specific rules, but an ant society as a whole behave according to rules of emergence manifesting a high order. Currently, the social scientists and information technologists are studying the phenomenon of self-organization of ant society with the hope to find out what could be applicable in the field of human society. Or, in case of traffic jam, each individual with a vehicle has a plan for his journey, but many individuals involved in traffic jam lead to an emergence which is not dependent on individual plans. Similarly, we can see the attributes such as "conscious", "creative" in human thinking are the emergence of nervous system cells.

The material world contains large numbers of complex systems such as galaxies, solar system, planets, ecosystems, organisms, cells, atoms, particles and quarks. Each separate system has its own laws. The building of an overview, unified theory of complex systems is the goal of complex science.

The complex systems exist in a state of the boundary between chaos and order, so the study of complex systems often need to chaos theory[7]. This theory describes the method used to describe the mode of behavior of a nonlinear dynamical system characterized by sensitivity to initial conditions. Consequently, its mode of behaviour seems to be chaotic, even though its dynamics is deterministically described by differential equations. Meteorologist Edward Lorenz[8] used with model of calculation for meteorology and found that, when initial conditions change a little, then the results diverge from each other significantly. Obviously, it is difficult to know exactly the initial conditions of nonlinear dynamical systems, so it is difficult to accurately grasp its final results. This is known as the “butterfly effect”, a butterfly beating its wings in the Amazon could cause major storms in New York.

Along with the birth of cybernetics[9], information theory[10], systems theory[11], according to many researchers, it gave birth to a "new science" – complex science, and they predict that it will be the science of the XXI century. Even the American physicist Heinz Pagels (1939-1988) in "The Dreams of Reason: The Computer and The Rise of Sciences of Complexity" predicted that: "... the countries and peoples that master the new science of complexity will become the economic superpower, culture, and politics of the next century." It can be said that the scientific research in recent years has started authentication for that expectation. Many research areas of nature and society show that the systems of nature and society are complex systems. The natural world and society appear out in front of our eyes now more complex than what was envisioned earlier. This fact has spurred the birth of a field of new research - complex science. This science studies the phenomenon and the behavior of complex systems in many different fields, including first of all such issues as relationships, the effects of nonlinearity for chaotic behavior; the behavior of the system in the chaotic state, non-equilibrium; the self-organizing ability of the system; the ability to emerge of the system – which is considered the key to understanding the nature of innovation in the evolution of all systems, from biological systems, ecological systems to economic, social, human nervous system, the whole network system and so on.

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[7] Interdisciplinary research field emerged from the second half of the twentieth century by the efforts of Edward Lorenz, Benoit Mandelbrot, Mitchell Feigenbaum, James Gleick.vv. Today it is commonly applied in such fields as geology, mathematics, molecular biology, computer science, economics, meteorology, physics, political science, demography, psychology, philosophy, automatics.etc.

[8] Edward Norton Lorenz (1917 - 2008), the American mathematician and meteorologist, and a pioneer of chaos theory. He coined the term “butterfly effect”.

[9] An interdisciplinary field emerged in the early 40s of the twentieth century, including sectors such as control systems, electrical network theory, mechanical engineering, logic modeling, evolutionary biology, neuroscience . etc.. The pioneering scientist ones include Norbert Wiener, Ross Ashby, Grey Walter, John von Neumann, and Heinz von Foerster.

[10] A research arm between applied mathematics and electronics engineering refers to the amount of information provided by Claude Shannon built in the 40s of XX century. Been widely applied in areas such as statistical inference, natural language processing, cryptography, neurobiology, quantum computing, database.etc.

[11] Interdisciplinary research field appeared after World War II through the merits of Ludwig von Bertalanffy, Anatol Rapoport, Kenneth E. Boulding, William Ross Ashby, Margaret Mead, Gregory Bateson, C. West Churchman. The purpose of systems theory is to find the principles applicable to all types of systems in the physical world.

As mentioned above, the complex science has brought new awareness of reality, and to capture new properties of reality, requiring a new method of thinking. Thus it emerged the idea in terms of the methodology from the complex science, which may include the trend of complex thinking (Pensée compexe) whose father is French theorist Edgar Morin (1921 -)[12]. Basically, Morin said that science today should be added to the thinking mode of separation called reductionism with the thinking mode of complexity. Complex thinking is a mode of thinking to distinguish but not separate, to link but not reduce. According to Morin, with complex thinking, reality is reflected comprehensive, truthful and vivid as it is, not only the order but also chaotic, and not just the balance but both balanced and non-equilibrium; not just stable but both stable and changeable; not just linear but both linear and non-linear; not just organized but both organized and disorder; not just deterministic but both deterministic and non-deterministic and so on.

From the Morin's concept of complexity, it can be seen through Marxist language, reality is multi-layered contradictory, multi-layered dialectical. In addition, the content of the Morin complex thinking is not entirely a style of thinking to eliminate the certainty with the uncertainty, the separation with the alignment, or the inevitable with the random, but it is the kind of thinking to operate between the deterministic and uncertainty, between the part and whole, between the separate and align, or more generally, operating between the opposites. Complex thinking does not negate the fundamental principles of mechanical thinking, but it is expanded, enriched by the unity, integration of the opposites in mechanical thinking. Complex thinking is not as opposed to the mechanical one, but a new synthesis of the opposites of the mechanical thinking. It has the ability to link and interlock, braide, gather, but also be able to distinguish the individual and the particular.

Science has long been considered as a task to go beyond the complex surface of the phenomenon in order to reach the order that dominates phenomena. However, reductionistic way of thinking does not reflect the full, complete objects, so the problem arises. How can we consider the complexity without reductionism, not simplification? So, it could be that the birth of complex thinking is one of the efforts for the needed responses.

As shown above, the characteristic of complex thinking is an effort to reach a knowledge not local, not separate, not reductionistic, and acknowledge all knowledges are endless, imperfect. It is a multi-dimensional knowledge, multi-line, multi-tier overlapping layers. This is logical because the world of phenomena is multi-complex, multi-conflicts, the interlocking ones, events, actions, decisions, interactions, feedback which are variable, hardly unexpected. Appearance is tangled, messy, disorder, ambivalent, ambiguous, vague, and uncertain. Thinking has a duty to remove what is disordered and chaos, to make clear, to bring order, but needs to alert the extreme trend, absolutization. Because, for example, there are chaos to be removed, rearranged, but there are also chaos to be maintained to grasp all relationships, the impacts of them. In the physical world, there is a principle of decline and disorderly chaos (second principle of thermodynamics). In the world of micro-physics, particles are

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[12] View Edgar Morin (2009), Introduction to complex thinking, translated version by Chu Tien Anh and Chu Trung Can, Tri Thuc Publishers.

not "first basic bricks", but they can be a different multiplicity which is difficult to be imagined in a normal way (the string). Those suggest the universe is no longer considered already a perfect machine but always simultaneously an endless process of formation and transformation.

From the methodological point of dialectical materialism, we give some discussion of characteristics is considered new, peculiar of the complex systems and realistic picture behind these complex systems.

Emergence can be completely interpreted in the light of a very familiar rule of materialist dialectics, namely the rule of transformation from the quantitative to the qualitative and vice versa. The appearance of the rules, forms, the order and the new features from the collective effects of the interactions between the components of the system would be a strange phenomenon if not up to the motions and changes of each component in the entire system. This transformation at a certain point (node) when they meet the conditions of quantity has created new qualities in a system (jump). The problem here is that more research is needed to determine accurately, specifically how the processes, modes of motion and transformation of the whole system lead to the appearance of new qualities. Emergence can be seen as a local jump of a complex system.

The new picture of the real world derived from complex systems in the position of the complex thinking is nothing new in comparison with the world view of dialectical materialism, in which the reality is endless, constantly moved and transformed by its inherent laws, of which the highlights are the rules of the relationship and the development, and conflicts are the source and motivation. The fact that the real world before us is simple or complex depends on the level of specific-historical knowledge of each human generation. Thus, the birth of complex science shows the level of development of human thinking now, but not completely creates nothing new into the level of motion and development of the material world itself, not to have the world at present complex, while the past was simple.

Morin’s mode of complex thinking has many similarities with the Marxist dialectical one although it appears historically later. It is still in the process of formation as an idea, and obviously has not provided a complete system in terms of methodology like the dialectical materialism. Here appears the question, why do theorists of complex science not rely on materialist dialectical thinking as the basis and methodology for themselves, as we see clearly, materialist dialectical methodology are fully applicable? The answer to this question is beyond the framework of this article, but, in our view, this suggests a feature of the thinking of modern Western science. It is on the way forward spontaneously from metaphysical thinking to dialectical one under the strong pressure of reality rather than voluntarily step forward on the basis of mastering Marxist methodology?

Why is that? As an attempt to find an answer, we borrow the ideas of Engels in "Anti-Duhring": "Nature is the proof of dialectics, and it must be said for modern science that it has furnished this proof with very rich materials increasing daily, and thus has shown that, in the last resort, nature works dialectically and not metaphysically. But the naturalists who have learned to think dialectically are few and far between, and this conflict of the results of discovery with preconceived modes of thinking explains the endless confusion now reigning in theoretical natural science, the despair of teachers as well as learners, of authors and readers alike."[13] Engels had criticized scientists who tried to "dodge" dialectical thinking with assume that it will inevitably lead them to the mistakes, the inevitable deadlock. And more importantly, he has confirmed the essential relationship between science, especially natural science with materialism not only in terms of world view, but also in terms of methodology. We can confirm that research on complex science and methodological issues raised. It once again reinforces the value and sustainable vitality of dialectical materialism in the context of modern science today.

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[13] *K. Marx and F. Engels: Full Episodes: Episode 20, National Political Publishing House, (1994), p. 39.*