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THE IDEA OF COMPLEMENTARITY BETWEEN SCIENCE AND EDUCATION

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***Abstract*—The new scientific researches determine new interdisciplinary interpretations. Therefore, we consider that this idea can be justified by the fact that in a certain research field, the scientific community tends to use information from the most various fields. The passage from the interdisciplinary analysis to the transdisciplinary one reveals a new approach of knowledge. However, a maximum responsibility must be kept in terms of using the notions of inter- and transdisciplinary whatever the intended purpose in a certain research is. Consequently, unlike the interdisciplinary perspective where the knowledge is in a certain way limited between fields, in the transdisciplinary one the knowledge is open anytime towards possible worlds. The transdisciplinary understanding refers to the recognition of more reality levels at the same time. Thus, through a transdisciplinary approach a coordination of knowledge at all levels is observed. The information flow supposes a mentality opened towards the unknown. Subsequently, the complementary way of thinking from physics is transferred to other fields of knowledge as chemistry, biology, this one being analyzed on different levels of reality.**

Keywords: ***scientific complementarity, physics reality, demarcation criteria, inter- and transdisciplinary understanding, physico-chemical struture, biologic*** *process*

I. INTRODUCTION

In science, the idea of complementarity represents a relevant aspect from a scientific point of view. Thus, there are obvious the problems which suppose a conceptual coherence meant to justify the rationality of the scientific community. The complementarity constitutes a necessity in the approach of the complex structures through an inter- and transdisciplinary research. Such a complementarity is possible only if the image of reality sends to the idea of "responsibility". Any action specific to the thinking sends to a serious approach of reality. But the scientist must not be imagined as a responsible entity for the innovative ideas. His morality must show in the assumed scientific ideas too.

The researches done inside some fields as well as the results obtained (as the development of the microbiology and of biochemistry) can constitute consequences of the philosophical problems concerning the complementarity principle. Furthermore, understanding some consequences supposes taking into consideration the educational dimension which a scientific research implies. Being aware of the complementarity idea implies the divergence and the convergence of the theories which take into account a coherence of knowledge. Therefore, the reality can be rethought and described at the same time in terms of a conceptual device which considers the new results obtained inside the knowledge process.

II. SCIENTIFIC VALENCE OF THE COMPLEMENTARITY IDEA

The complementarity idea constitutes an important aspect which determines more and more different problems. Extended to the explanation of some processes from other fields, this idea expresses the fact that any form of scientific knowledge sends to the understanding of the physical reality from an ontological and epistemological perspective. Consequently, the fields of the scientific knowledge show a specific approach of the seen and unseen reality.

K. Popper blamed the complementarity principle of sterility in the physics field and found out that this one determined in fact only discussions and arguments which rather confused the opponents. However, K. Popper asserts that instead of having some expected results from the complementarity principle, other atomic results were obtained, more practical ones, some of them highly visible [1]. Otherwise, the problematisation need is considered during this period because the diversity of the obtained scientific results was found in the attempts of the scientific community to understand the expressions of the physical reality.

It is interesting the analogy that W. Heisenberg creates between physics and chemistry when referring to the "complementarity" notion. On one hand, the atom is described from the physics point of view as a planetary system at a small scale: in the middle there is a nucleus and towards the outside there are the electrons which surround this nucleus. On the other hand, the atom is described from a chemical point of view, in the sense that one can calculate its response temperatures in the case of combining itself with other atoms. In this situation nothing about the movement of the electrons can be predicted. Referring to these aspects, W. Heisenberg specified that even if they are different, both images are acceptable if they are applied at the right place and also if they contradict each other.

Analyzing the static character of the quantum theory, W. Heisenberg admitted the idea that there exist processes that

at a large scale can be predicted only statistically. For example, achieving a precise calculation regarding the explosion power of the atomic bomb it is impossible because this depends on the behaviour of some atoms in the ignition process. [2]. Therefore, W. Heisenberg states that there is the possibility that this situation is extended to biological processes, especially to gene mutations in the inheritance process. Consequently, W. Heisenberg indicates that there is a complementarity relation.

The physical-chemical life analysis is materialised in two orientations that are different by the conceptual device and the used research methods: the information orientation (with a theoretical pattern) and the structural one (analytical). The first orientation whose principal representative is M. Delbrück, states that the heredity study constitutes a fundamental field of the physics research. The second direction, whose representatives are F. Crick and J. Watson, admits that the life process can be explained through already known chemical and physical laws.

M. Delbrück, in his researches about the heredity, was inspired by the N. Bohr's ideas that were referring to the complementary aspect determined by a physical-chemical analysis of the neat structures, subcellular of the living against the research of the information connections. Thus, considered by M. Delbrück as a field of the fundamental physical research, the study of the heredity has as research object the way in which any living system can offer explanations about the discovering of some laws independent from the chemical structure of the living beings from the contiguous reality. Furthermore, the creation of the phage researching group aimed the achievement of a research programme regarding the physical origins of the heredity. The criteria of accepting the scientific theory are more than evident and justifying it is determined by the fact that the heredity research must star with the cellular level. Consequently, analysing the reproduction ways of the bacteriophages, the researchers tried to find out which are the conditions that determine the replication in a short time of the virus particle. These researches have been done on the Escheria coli bacteria using an unique category of phages (seven types of phages from the T series).

Discovering the DNA molecular structure, F. Crick and J. Watson analysed the molecular structure of the chromosomes and discovered that their structure is given by the Deoxyribonucleic acid, ribonucleic acid and other protein substances. They associated having in mind the modelling model, the DNA helical propeller. Using the Rosalind Franklin and Maurice Wilkins' spectroscopy information with X-rays (following the Roentgen diffraction researches), they succeeding in establishing the parameters of the double DNA molecule. Knowing these parameters determined the setting of the complementarity law specific to the nitrogenous bases according to which in the process of creating a bicatenary structure, the nitrogenous bases mate as follows: the adenine with the thymine (by tow hydrogen bonds) and the guanine with the cytosine (by three hydrogen bonds). Therefore, by the complementarity law of bases, the DNA molecule represented a weak departure point for the fusion of some new molecules with a complementary series of the bases, which assures the transmission of the information from one generation to another as well as using this information in directing the cell metabolism. Consequently, the DNA structure is stabilized energetically thanks to the interaction between the nitrogenous bases placed inside the double helix.

Otherwise, establishing the DNA structure by F. Crick and J. Watson was possible thanks to the success of Linus Pauling in the field of molecular biology. His researches concentrated on the protein molecule structure whose spine is covered following a helicoidal shape towards right or left. Therefore, the rest of the structure is determined by the exact linear series of amino acids along this helicoidal chain [3].

The problem of the DNA structure determined a complex recognition in the genetics field. In this respect it is known the Jacob-Monod pattern concerning the control of the protein synthesis at the level of the transcription of the genetics message from DNA to ARN messenger. In this context, we mention that the theory of genetic adjustment appeared after J.MOnod discovered the *diauxie* phenomena according to which the *Escherichia coli* bacterium grown in a glucose and lactose environment uses firstly the glucose until exhaustion and then, after a stagnation period, it grows again using the lactose this time. This pattern, postulating the existence of three types of genes (structural, regulatory, operator) found its utility in the explanation of the adaptive regulatory phenomena. Moreover, studying the originality and the evolution of the genetics code, F. Jacob admits the idea of the interaction between organism and environment.

Referring to the results obtained by Watson and Crick in relation to the DNA structure, J. Monod explains that the theory of the selective evolution acquired its significance as a result of the clarification about the structural bases concerning the invariance of the replicative gene. Therefore, Monod states that the only acceptable mutations are those which allow the enrichment of the teleonomic structure with new possibilities [4].

Admitting the distinction between the learning process and the selection one present in the description of the physical world, K. Popper admits that the world is a dual one, composed out of different structures. Karl Popper states that by "structure" he understands what François Jacob calls „integron" in the paper *The Logic living Systems: a History of Eredity*, Allen Lane, London, 1974, pp. 299-324. Thus, the big structures (the atoms, the molecules, the organisms, the solar systems, the galaxies etc.) are the result of the smaller structures (elementary particles). The learning process helps their growth and the selection one can determine both continuing as well as their disappearance. The analogy with the origin form sends to the replicative process but also to the linear structure of the DNA molecule represented by four basic complementary colours (red, green, blue, yellow), so the complement of a series will consist in another series where the red is replaced by green and the blue with yellow and the reverse. [**5**]. Consequently, K. Popper states that it can be admitted the compatibility between the dual image of the physical world which cannot

be determined at an elementary level and the image of the world determined at a macro-physical level.

The analysis of the complementarity idea in the organization levels highlights the existence of a "paradox of the hidden parameters". Such an example can be given from biology where was found that "the detachment of only electron from a gene can cause a decisive mutation which would explain the appearance of an essential biological character and, eventually, by selection, of a new species. The paradox consists in the fact that the analysis of the most elementary particles leads to complex explanations.

The results obtained after the analysis of the idea regarding the scientific complementarity and its extent to the biology field revealed a terminological problem which was also detected by N.Bohr. This problem is that, even if one can talk about an analogy between the atomic processes and the biological ones, one must take into account the existent exclusiveness between the individuals' self-preservation and regeneration, on one hand, and the division of the object on the other hand. Stating that the quantum theory cannot offer a adequate basis for the biological systems study, N. Bohr asserts that the existence of life must be considered in biology as an elementary fact as well as the action quanta is considered in atomic physics as a basic element which cannot be inferred from the considerations of the usual mechanics [6]. However N. Bohr underlines the fact that the vital and animistic arguments are used complementary to the description of reality as a system. Moreover, one can admit the idea of complementarity between the vital and animistic arguments when the reality interpretation is also taken into account. Consequently, the Danish physician demonstrates that the idea of a complementarity between these processes can be accepted, but with the reserve that it is impossible to bring simultaneously these two processes in a exact theoretical construction and in this respect there is necessary some complementary biological laws which satisfy the biological problems.

Between the biological research and the physics one cannot draw a demarcation line. Showing that this situation implies a terminological problem, N. Bohr underlines that the analogy between the aspects specific to atomic physics and biology supposes exclusiveness between the individuals' self-preservation and regeneration, on one hand, and the division of the object on the other hand. According to this complementarity can result the idea of the applicability in biology. . Consequently, the Danish physician shows that one can talk about a complementarity between the atomic and the biological processes not in the sense of a precise theoretical construction, but rather in the sense of the satisfaction of some biological problems.

N. Bohr shows that the comparison between the living organisms and the cars isn't relevant no matter how powerful they may be. Taking into account the fact that the chemistry as well as physics are based on the quantum theory, we cannot say the same thing about biology. Thus, the attempts to introduce a law from biology are considered irrationals, being incompatible with the laws of physics and chemistry.

However, analyzing N. Bohr's arguments according to which between biology and quantum theory there is incompatibility, H. Stapp shows that these one are not convincing enough. He notes that relation between physics and biology corresponds to the relation between simple and complex. Thus, the simplicity corresponds to the physics system and the complexity to the biology one. In the first case, the atomic system regarded as a 'black box' is responsible for the changing of the observable information concerning the preparation devices for statistics reports. In the second case, the information can be assessed by the biologist even if his attempt to achieve a similar calculation corresponding to an atomic system is doomed to failure. H. Stapp's conclusion is that science must be seen as a creation of thought which has the responsibility of the objective reality description. This situation will send to a subversion of the complementarity idea referring to the difficulty of mind-brain problem encountered at R. Descartes. Consequently, in a strategy of individualization regarding the cognoscible examples, we consider that must be considered the fundamental and the instrumental aims as well as the epistemological condition necessary for that system.

In this respect we consider that the attempt to correlate certain aspects of the quantum theory in biology is acceptable. Moreover, the analogy and the correspondence must be taken into consideration also in the case of other fields if the thinking has the power to continue on the knowledge area.. The relation between simple and complex must consider a possible world where the correspondence must be considered as a criterion in the knowledge analysis. It is a difficult task but not an impossible one for the researchers. The history confirmed this thing if we consider the scientific innovation. In case of obtaining new scientific results, we believe that the researchers must not hurry to indicate that through the emergence of the new theory, the physics knowledge improves and deepens, as well as the researcher should not be overzealous when arguing for the idea that the new theory establishes certain limits where can be applied the concepts of the earlier theory. In this case, it is about something that certain authors call a correspondence relation between fundamental theories from the science philosophy.

III. THE COMPLEMENTARITY IDEA AND THE EDUCATIONAL DIMENSION F THE SCIENTIFIC KNOWLEDGE

The idea of describing phenomena of the physical reality without taking into account a certain risk that they imply (situation underlined by M. Born) can help solving some difficulties from biology and psychology. Thus, a living being (plant or animal) represents not only a physical-chemical system, but also a picture of the spirit expression which requires a description through concepts and different representations. Analyzing this aspect, M. Born shows that N. Bohr suggested also in this situation the idea of the existence of a complementarity, considering that the research of a biological process or a psychological one must be realized using physical devices which disturbs the process itself.

An interesting problem regarding the interpretation of the natural laws concerns an inherent aspect of any type of approach, as the following: the scientific community which

investigates the physical reality and the laws specific to this universe must consider quality and quantity criteria in the structure of the natural laws (scientific). The complementarity idea extended to other fields includes various meanings. It is about a contradictory complementarity considered by Ş. Lupaşcu the postulate itself of the scientific method. Furthermore, Ş. Lupaşcu analyses the "complementarity" notion from physics for which he discovers as fundamental features the contradiction and the antagonistic dualism [7]. Perhaps not by accident, in the science philosophy, in the approach of the complementarity problem, one can talk about and epistemological orientation (N. Bohr) or a ontological one (W. Heisenberg). Referring to the waving aspects as well as the corpuscular ones, W. Heisenberg's ontology shows the universe state is put into relation with the operators associated with spatial-temporal points. N. Bohr's epistemology sends to the idea of a pragmatic character which is visible when the Danish researcher states that the aim of the quantum mechanics formalism consists in understanding the experiments and the observations resulted.

H. Stapp admits that the ontological approach is superior to the epistemological one by the fact that this one can offer information concerning the connection mind-brain. Starting with the "facilitating" process present in the dynamic of the brain, he states that the description of the nature from a physicist point of view can be materialized through the acceptance of the consciousness in this process. Science must be regarded as a creation of the thinking that has the responsibility of the objective description of reality. Therefore, the operational specifications, as descriptions of the human experiences, do not depend on the subject which experiences. This way, the science objectivity is assured.

The sociology field the complementarity idea is found in the study of human cultures. Talking about the multiplicity of logics in the description of a physical system, R. Omnès demonstrates that people's freedom of expression is such model. For example, any marriage can have consequences explained differently from the perspective of monogamous, polygamous or polyandry law. N. Bohr still states that in the research of human cultures the complementarity notion must not be considered stricto senso as it is in physics or psychology. This situation is justified by the fact that some difficulties appear when one is seeking to characterize the culture of a society depending on the traditions of another. A gratifying aspect of this process is the one that consists in the conservation of the most valuable aspects of national traditions as a consequence of the contacts between nations.

The interpretation of the social relations in terms of the complementarity principle appears as a way of social expression of mentalities. But changing the mentality means social adjustment and the social differences are only levels of organization. The complementarity results exactly from the originality of organizing the social relationships. The concrete example that N. Bohr gives in this case is the one that concerns the relations between different human cultures studied by ethnologists. Furthermore, the model of family life is different from one community to another, detecting a separation between the roles of women and men. Subsequently, the complementarity idea appears when one is aware of the equilibrium between traditional conventions. Therefore, the emergence of a new culture is the result of the fusion between the traditions. Moreover, this situation reveals an exchange of roles between genders. Consequently, the system of a national culture has as specific feature the community mentality itself. The intersection concerning the traditions of the different communities creates common values and the informational message can acquire a form of expressing characteristic to the complementarity idea. The convergence between cultures expresses an image in which the mentality of a community often becomes prejudice to the other.

Referring to the role that has the relation between culture and complexity by reference to the concept of 'complementarity', E. Morin distinguishes between the reproduction of the culture in each individual (in the sense that any form of culture is always reappearing as a biological organism is perpetuating itself by replacing dead cells with new ones) and the self reproduction of culture (for example, the reproduction of a society from a young colony already formed culturally which takes distance from the old colony in the same way which occurs the process of self reproduction of a bacteria by scissiparity. Thus, the culture is a generative system highly complex [8]. The idea sustained by E. Morin is that any form of culture may not materialize itself ex nihilo, but on forms of pre-culture complexity of the society.

However, culture does not replace the genetic code and, therefore, the organization principles can be explained based on the complementarity idea which exists between natural abilities (innate organizational skills) and the existence of the culture itself. Moreover, the culture itself emphasizes a complex social relationship. Therefore, the complexity is present at different levels of organization as it was highlighted by the latest scientific developments. All these developments represent a complex process characterized by the emergence of new theories (paradigms) meant to replace or supplement the previous ones.

The gradual development of science has allowed the emergence of some abstraction scientific methods. By condensing the information appears a whole alphabet of symbols and the language becomes increasingly abstract. The fields where such situations are visible are the physical and the mathematical ones, where some terms are replaced with symbols. For example, in chemistry, physics and biology the understanding process is reported to the possibility of formulating an explanatory model. But this model which must be explained in terms of a common language to be understood by people who have skills in that domain, result from the creation and acceptance of a mathematical formalism. In other words, this conceptual mathematics device is the result of the correlation between some experimental facts concerning the phenomenon which must be explained. Therefore, with this mathematical model, the reality is described by symbols.

If at first was "simplicity" [9], then explaining the origin of the universe acquires complex meanings. With this sentence starts the chapter „Replicators" from the work

Egoist Gene of Richard Dawkins. In the approach he proposes the author sends to the famous C. Darwin's theory about the evolution by natural selection. This theory is, in fact, an understanding of simplicity, but also a picture of how the simplicity can become complex. Under these conditions, the natural selection expresses the law of conserving the stability. Therefore, R. Dawkins examines in a new light C. Darwin's evolutionary theory. Thus, showing that the survival of the most adapted is a special case of a more general law, R. Dawkins describes the simplicity with the concept of 'stable structure of atoms." This description refers to the most basic processes from the micro universe. The supported idea is that before life appeared on earth, because of some normal physical and chemical processes, there is a rudimentary development of molecules. However, the basic principles of this development are not the key - elements through which can be explained complex entities, such as man. Recognizing that his idea about the origins of life is a speculative one, R. Dawkins admits that at one point in the first moments after the accident, a molecule was formed having the property to create its own copies. Gradually the elements of this replicate (which, otherwise, is the modern equivalent of DNA) were developed giving rise to some stable structures.

However, throughout this development, some errors appear whose number increases because some copies are made from other copies. Thus, one can accept the idea, says R. Dawkins, that the occurrence of some errors in the progressive development of life was essential. Hence, it follows the idea that longevity replicates have three fundamental features: the ability to reproduce, the replication speed, the precision in the replication process. In this way, we can support that the situation described represents, in fact, the acceptance of the complementarity principle which offers an explanation of the helical structure of DNA

IV. CONCLUSIONS

The value expression reveals a content which is relates]d primarily to a model of scientific practice. On the other hand, the conceptual and problems frameworks express an investigation of the inter subjects, and the existing processes on different levels of reality point to the simple-complex relation. Knowledge is currently an open structure resulting from the uniqueness and the diversity of thought.

In this context, we consider for example that the emergence of the concept of "cuanton "by accepting the complementarity idea, can provide a transdisciplinary understanding because the thinking in this situation reveals the existence of several levels of reality. Thus, the criteria of a transdisciplinary model are accomplished: the multidimensionality of the object (the acceptance of the reality levels), the multireference of the subject (the existence of the perception levels) and the vertical access to knowledge. In other words, the experience information reveals by itself response in accordance with the very notion of 'complementarity'. The idea of a complementarity relation between local and final causality (teleological) is extended by N. Bohr to the vital processes. Moreover, admitting the existence of a omnipresent principle, N. Bohr suggest in his work the idea of a possible correlation between fields as physics, sociology, etc.

We gave an important role these issues (scientific and educational practice) for two reasons. The first emphasizes that both the complementarity idea and the scientific research suppose a methodological dynamic at a theoretical level. Thus, the scientific theories that deal with these issues reflect the fact that the problem they involve will always remain open to any interpretation. The second reason (which justifies otherwise, the order in which we approached this research) shows that these issues require by their interpretation technique a conceptual dimension specific to the inter-and transdisciplinary approaches.

The conclusion to be drawn is that the complementarity principle preserves even today the diversity of theoretical implications. They express in the philosophy of science a new image on the relations between the organic and inorganic world. That relationship represents the complementarity notion itself. However, it may be admitted interpretations that suggest references to the complementarity principle when other issues situated on different levels of reality are also studied. The various analogies with the complementarity principle allow philosophical theories meant to restructure the process of thinking itself.

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