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Levels of Oraganization of Scientific Knowledge

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***Abstract*—The article deals with the levels of organization of scientific knowledge. It is substantiated that every developed branch of science includes four levels of knowledge: perceptual, empirical, theoretical and meta-theoretical ones. Though being interrelated, the levels aren't derived one from another. The reason is that each level has its own ontology and methodology. The interlevel relation is of constructive-interpretative character.**

Keywords—scientific knowledge; level of scientific knowledge; perceptive scientific knowledge; empirical knowledge; theoretical knowledge; metatheoretical knowledge

I. Introduction

As a rule only two levels, empirical and theoretical ones, are distinguished in the structure of scientific knowledge. It's insufficient for adequate understanding of the structure of scientific knowledge, methods of its construction and substantiation. The analysis of the real structure of developed scientific disciplines reveals its level character. The structure of scientific knowledge comprises four levels. They are as follows: perceptive, empirical, theoretical and meta-theoretical. The levels differ in ontology, acquisition method and that of substantiation. Their functions in scientific cognition are also different [1].

II. The Levels and Structureof the Perceptual Level of Scientific Knowledge

This level of scientific knowledge is formed by observation and experimentation data acquired through readings of various scientific instruments. Perceptual knowledge acquisition is dependent on the instruments developed on the basis of certain theories. It is also dependent on the directing role of researcher's cognitive and practical interests and further empirical and theoretical interpretation. Despite this fact, perceptive scientific knowledge has its foundation and criterion of objectivity. The norm of perception can be considered such a criterion, and it is the same for all scientists. The nature of this norm is beyond science and has biological and adaptive basis. In this respect, it is a generally valid basic structure of consciousness possessing an objective character for all scientists. The results of sense perception of observation and experimentation are invariant for all scientists and form what H. Poincaré called "bare facts", which constitute fundamentals of science [2]. Things are different when it concerns scientific facts. They represent some discoursive model of "bare facts", the result of mental processing of these facts in terms of a certain scientific language. But scientific facts are already elements of empirical level of scientific knowledge, the level representing the integrity of perceptive knowledge and thinking, the result of mental processing of perceptive data in mind (I. Kant). No matter how abundant data acquired by observation and experimentation are, they can be considered scientific knowledge only when represented in a symbolic or conceptual form (schemes, graphs, notions and sentences of empirical language, etc.). V. A. Smirnov was the first Russian philosopher who paid attention to this phenomenon. He stressed the necessity to distinguish the two cognitive oppositions: "perceptive – rational" and "empirical – theoretical" [3]. The opposition "empirical – theoretical" already exists in rational knowledge, thus, there exist two types of rational knowledge. The boundaries of empirical cognition are to great extent determined by the operational faculties of mind. Its function is to apply to the material perceptive data of various logical operations, such as abstraction, analysis, comparison, generalization, induction putting forward hypotheses of empirical laws, deductive derivation of testable consequences from them, their confirmation and refutation. In fact, empirical knowledge is a set of sentences about empirical (abstract) objects, and it can be represented through a long chain of interpretations and identifications.

III. The Nature and Structure of the Empirical Level of Scientific Knowledge

Being very much alike in their content, perceptive knowledge and that of empirical one, however, don't logically derive from one another due to the different forms of existence and representation: the former comprises a set of perceptive (sensual) images, whereas the latter – a set of empirical sentences. First, empirical knowledge shouldn't be understood as logical generalization of observation and experimentation data; second, these data aren't logically derived from empirical sentences. There are some other kinds of interlevel relations. They are as follows: modeling (representation) and interpretation (reduction). Empirical knowledge is a conceptual-discoursive representation of perceptive knowledge, the last mentioned being one of the forms of empirical knowledge interpretations.

The relation of logical derivation exists inside empirical knowledge. The last mentioned has quite a complicated structure. The basic constituent part of empirical level consists of single sentences (statements) (either with or without an existential quantifier). These are so-called protocol sentences. And they are the results of single observations turned into a discourse form. While making a protocol, the exact time and place of observation are fixed. Scientific facts are the second part of the empirical level structure. They are inductive generalization of protocols. Scientific facts are general statements of statistical or universal character, they register some properties and relations of a subject domain under investigation and their quantitative characteristics. The symbolic representations of these properties and relations are graphs, diagrams, tables, classifications, mathematical models, etc.

It is necessary to note that empirical cognition, alongside with its protocols and facts, is always determined by some theory. As a rule empirical cognition has confirmation or refutation of some theoretical idea or hypothesis as one of its aims. It isn't worth speaking about absolutely "pure" and independent of any theory facts of a developed branch of science. It's an axiom in modern philosophy.

The third structural element of empirical level is represented by empirical laws of various kinds: functional and structural ones, those of dynamics, statistics, etc. A scientific law is a description of specific interrelations of events, states or properties which constantly exist in time and space (regularity). As well as facts, empirical laws are general (universal or statistical) sentences with the existential quantifier: $\forall x(a(x) \supset b(x))$ ("all bodies expand when heated"; " all metals are electro conductive"; " all planets go round the Sun in elliptic orbit", etc). Empiric knowledge is a conceptual and discoursive model of perceptual knowledge [4]. Completeness of perceptive knowledge is vaster than that of empirical one, the latter modeling only part of the content of the former. As for the subject-matter, an empirical object is just part of a perceptive object, which in its turn is only an aspect of a thing-in-itself. Thus, empirical knowledge represents the second level of abstraction with respect to real objects or things-in-itself (Kant).

IV. The Nature and Structure of the Theoretical Level of Scientific Knowledge

Reason produces theoretical knowledge. Contrary to Mind, the function of Reason is directed inside consciousness in order to reveal its own subject-matter [5]. Being self-contained, Reasoning can be defined as free cognitive creativity. The main logical operations of theoretical thinking are idealization and intellectual intuition. Both of them are aimed at creation of so called ideal objects. It is the world of ideal objects that represents ontology of theoretical level of scientific knowledge.

Scientific theory is a logically organized set, logically organized system of statements about a definite class of ideal objects, their properties, interrelations, changes. This idea is thoroughly and convincingly considered in the book "Theory and its Object" [6]. The examples of objects in various areas of science are given below. In mathematics they are: geometric point, line, plane, number; in physics: inertia, absolute space, perfectly elastic liquid, mathematical pendulum, absolutely black body (Planckian radiator); in sociology: strata of society, socioeconomic formation, civilization; in logic: logical thinking, logical proof, logical functions, etc.

How are ideal objects created in science and what's the difference between them and empirical objects? Idealization is the main means of creating. Idealization is a mental transition (transmove) from the properties of perceptive objects under observation to their maximum/minimum logically accepted values. For example: geometrical point is zero dimensional, thus, being a logical minimum of spatial characteristics of any perceptive object; absolutely black body is the object capable of absorbing all light energy scattered on it; line is a continuum of geometrical points. What can characterize the limiting process when ideal objects are created? Three facts are of primary importance. The first one is: empirical object, its properties and relations, provoke motion of thinking process. The second: the motion is quantitative increase or decrease in intensity of the property under observation up to max/min acceptable values (0 or 1). The third and the most important one: a purely quantitative at first sight motion creates a qualitatively new object possessing such properties that can't be observed in principle (zero dimension of points, absolute straightness and homogeneity of a line, actual infinite sets; socioeconomic formation; Being and Consciousness, etc) [7]. Ideal objects of scientific theories are constructed fromempirical objects by means of constructive addition to them such properties, which can make ideal objects unobservable in principle and thus,they become immanent elements of thinking.

There's another smarter way of constructing ideal objects. It consists of just constructive introduction of them in order to solve definite theoretical or logical problems. This method found its application only in mathematics and that happened in the latest period of its development (introduction of irrational and complex numbers into solving algebraic equations, introduction of various mathematical objects into topology and functional analysis, etc). Later this method was used for constructing ideal objects in mathematical logic, theoretical linguistics, etc. The method has been intensively applied since the late 19thcentury when non-Euclidian geometries were acknowledged as valid mathematical theories. Being free from the necessity of correlating its own objects with those of empirical ones, mathematics boosted its development. When modern mathematics is defined as the science of "abstract structures" (according to N. Bourbaki) or the science of "possible worlds" (according to L.W. Wittgenstein), it's implied that the subject-matter of mathematics is ideal objects constructed and introduced by thinking.

Besides idealization, such methods of theoretical scientific cognition as thought experiment, mathematical hypothesis, theoretical modeling, axiomatic, genetic method for constructing scientific theories are of great importance. Why are ideal objects introduced into science? To what extent are they necessary for its successful functioning and development? Is it possible to do only with empirical objects and empirical knowledge which is mostly used in practice? E. Mach was the first to ask and answer these questions in a clear-cut form. He thought that the main aim of scientific theories is their ability economically represent and codify all empirical information about a definite data domain [8]. To achieve this aim is to develop such theoretical and logical models of empirism when a maximum number of empirically confirmed consequences can be derived from a minimal number of theoretical assumptions. The introduction of ideal objects is the price thinking pays for achieving the aim mentioned. According to Mach, it can be explained by the fact that objective reality lacks logical interconnections between its laws, properties and relations. Logical relations exist only in thinking itself, among its concepts and judgments. Theoretical-logical models of empiric reality requireit to be simplified, schematized and idealized. It is also necessary to introduce a number of concepts which aren't of an empirically descriptive character, but of an instrumental one. All above mentioned contributes to the creation of holistic, logically organized theoretical systems of knowledge. According to Mach and Duhem, the main merit of theories is that empirical information represented in scientific theories is stored, defended from being lost, and transmitted through culture. It is also quite observable and can be acquired in the course of studies.

V. The Meta-theoretical Level of Scientific Knowledge, Its Nature and Structure

In the structure of scientific knowledge, it is necessary to distinguish another level, more generalized than the theoretical one. This is a meta-theoretical level of scientific knowledge. It consists of two sublevels: general scientific knowledge and philosophical foundations of science [9].

General scientific knowledge consists of the following basic elements: 1) the general scientific picture of the world; 2) general scientific methodological, logical, axiological principles. It is necessary to note that the meta theoretical level of knowledge plays an important role not only in natural sciences and social sciences but also in mathematics. In mathematics this level is represented by two disciplines: meta-mathematics and meta-logic.

The subject-matter of those two is to investigate consistency, completeness, independence of axioms, argumentativeness and constructiveness of mathematical and logical theories. In natural sciences, social sciences and the humanities, meta-theoretical level exists as the corresponding pictures of the world and general scientific and philosophical principles. It is necessary to stress that in modern science there's no unified in subject-matter and generally accepted meta-theoretical knowledge, the last being always concretized and to great extent associated with the features of scientific theories. What is a scientific picture of the world? It is a prevailing in science as a whole or in one particular branch of science number of views of the world (physical, biological, chemical and other pictures of the world). For example, the following ontological principles constituted the basis of physical picture of the world existed in classical natural sciences: 1) discrete character of the reality which consists of self-contained bodies interacting by some forces (gravitation, repulsion, etc); 2) all the changes of the reality are governed by the laws of an unambiguous character; 3) all processes take place in an absolute space and depend neither on the matter of the process, nor on the choice of a reference system; 4) all bodies interact instantly; 5) necessity is primary, contingency is secondary; contingency is the manifestation of necessity in certain interactions (the intersection point of independent causative series), in all other cases contingency must be understood as the measure of unawareness of "the true state of affairs"[10].

The majority of these principles were a constituent part of Newtonian mechanics. As for biology of the classical period, it is known that the foundation of the biological picture of the world was Darwin's theory of evolution based on the mechanism of natural selection. Later the theory was supplemented by the ideas and principles of genetics. What is the role and significance of the picture of the world in scientific cognition? It is the picture of the world that functions as true categorical type of vision. Using it, science harmonizes its empirical and theoretical objects. What is, in general, the nature of the scientific picture of the world? First of all, it is necessary to stress that the picture of the world doesn't result from the generalization of present theoretical and/or empirical scientific cognition. On the contrary, it is prior to cognition due to being the concretization of a certain philosophical ontology. The last mentioned is the product of reflexive-constructive mental process in relation to oppositions and distinctions. Being the result of philosophical creativity, philosophical ontology always has a concrete historical background.

As a rule, the role of the general scientific picture of the world is bestowed on one of the definite pictures which dominates in science in a particular epoch. For example, once it was the physical picture of the world, developed in Newtonian mechanics. "Mechanisizm" marked the recognition and assertion of the physical picture of the world as the general scientific one and mandatory for all the sciences (chemistry, biology, geology, astronomy, physiology, even political science and sociology). In non-classical natural sciences the position of the general scientific picture of the world was still claimed by the physical picture, but the one that formed the basis of the theory of relativity and quantum mechanics. Yet, classical and non-classical physical pictures of the world contradicted to each other to a great extent.

The presence of two rivaling theories in physics based on different pictures of the world dramatically undermined the reputation of the physical picture of the world as the general scientific picture. Gradually was growing the idea of creating the general scientific picture as the synthesis of pictures of various fundamental sciences. For non-classical natural science, the synthesis of physical, biological and theoretical-system pictures has become the general scientific picture of the world. Modern post-non-classical natural sciences are attempting to supplement this synthesis with the ideas of wisdom and reasonability of existence. Due to its degree of generalization, the modern general scientific picture of the world is getting more and more in common with philosophical ontology [11].

The same tendencies of pluralization and universalization can be traced in such elements of meta-theoretical knowledge as gnoseological and axiological principles of science. Well known examples of those principles within the framework of physical cognition are, for instance, the principles of correspondence and complementarity (N. Bohr), observability (E. Mach), the priority of the quantitative (mathematical) description over the qualitative one (G. Galilei), the dependence of the observance data on the conditions of cognition (N. Bohr) and etc. Today the majority of these principles claim for the status of general scientific ones. The same status is claimed by the principles conceived in the womb of modern mathematical cognition. Gödel's incompleteness theorems, the contextuality and intuitivity of scientific knowledge (H. Poincaré) are just a few of such principles to be mentioned. Various methodological and logical rules and imperatives exist within the framework of meta-theoretical scientific knowledge. And they are different not only in different sciences, but they may differ across the stages of development of one and the same science. There's an obvious distinction between the methodological tools of mathematics and physics, physics and history, history and linguistics. But methodological discrepancy within one and the same field of science can be glaring. The difference between Aristotelian physics (qualitative-speculative) and classical physics (experimental-mathematical) can serve an illustration for that. What causes the differences in methodological requirements and rules? On the one hand, it is the variety of objects and phenomena under study. On the other hand, it is the difference in understanding the aims and ideals of scientific cognition. For example, ancient Greek and ancient Egyptian geometry had the same subject-matter: spatial properties and interrelations of real objects. But if the ancient Egyptians used the method of multiple measurements to acquire knowledge of them, the ancient Greeks used the method of logical derivation of geometrical knowledge from simple and obvious axioms. This distinction in methods of geometrical cognition was caused by the different understanding of aims and ideals of scientific cognition. For the Egyptians, that was the aim of gaining practical, useful knowledge (it could be approximate), whereas for the Greeks, the aim of science should have been acquiring only true and provable knowledge.

The problem of the aims and values of scientific cognition is the main subject-matter of axiological prerequisites of science. It is important to distinguish between the inner and outer axiological prerequisites. It is the inner axiological prerequisites of science that represent immanent aims and values for science, unlikely other kinds of cognitive and practical activities. They can be as follows: objective truth, definiteness, accuracy, evidence, etc. In the Russian philosophy of science, the inner values of science are called "ideals and norms of scientific investigation". Ideals and norms represent some methodological standards, regulating means of correctness and legitimacy of scientific activity. They are also considered the criterion of quality and acceptability of scientific products (e.g. observation, experimentation, facts, laws, conclusions, theories, etc.) [12].The outer axiological values of science are the values directed beyond science, and they regulate its relationships with society, culture and their various structures. Among those values, the most important ones are as follows: practical usefulness, effectiveness of science and scientific knowledge, increase of intellectual and educational potential of society, contributory influence on scientific and technical, economic and social progress of society, growth of adaptive abilities of mankind in the interaction with the environment, etc. It is well shown in modern historical-scientific and methodological literature that the set and subject-matter of inner and outer values of science are different not only for different sciences in a certain period of time, but they also differ in the course of historic development of one and the same science [13, 14]. For example, the value of logical evidence of scientific knowledge and its axiomatic construction is of primary importance in mathematics and logic, but it isn't that important in history, literature studies, even in physics. Chronological accuracy and completeness of description, adequate understanding of historic events and the evaluation of the significance of sources are in the foreground of historical sciences. The following values are of primary significance in physics: empirical reproducibility of events, accurate quantitative description, experimental confirmation of facts and theories, practical (both technical and technological) applicability of physical knowledge. The last mentioned is the leading one in engineering sciences. The structure and subject-matter of inner and outer values of a definite science aren't permanent and unchangeable in various historic periods, at the same time they aren't permanent and unchangeable in the development of science as a whole. For example, the understanding of the notion "evidence (proof)"is different in classical and constructive mathematics, in Aristotelian physics and in Newtonian physics, in introspective psychology of the 19thcentury and in modern experimental psychology, etc. [15].

One of the problems much debated on by positivists and their opponents in the 19-20th centuries and still hasn't been solved is the problem of the status of philosophical foundations in the structure of scientific knowledge. The main point of the discussion is whether to include philosophical foundations of science in the structure of scientific knowledge or not. Basically, no one denies the influence of philosophy on the development of scientific achievements and on their evaluation in particular. The history of science and the position of outstanding scientists on this problem leave no doubt about it. Nevertheless, positivists insist on the fact that the influence philosophy has on the process of scientific cognition is shallow, that philosophical foundations shouldn't be included in the structure of scientific knowledge, otherwise the relapse of natural philosophical speculations may threaten science. Is it really so? To what extent are the philosophical foundations of science interrelated with its general scientific foundations and, what is more important, with the theoretical level of scientific knowledge? Let me give some real historical examples of the philosophical foundations of science. They are: "Space and time are independent of one another separate substances", "Numbers are the entity of the world", "The laws of nature are unique", "Casualty has a universal character", "Space and time are attributive and relative", "The axioms of theories are intuitively obvious and true statements", "The world has a discrete structure", "The world is a continuous reality, because nature abhors a vacuum". There are different kinds of the philosophical foundations of science according to various philosophical studies: ontological, gnoseological, methodological, logical, axiological and social. To my mind, the history of science proves that the interrelations between scientific theories and their philosophical foundations are ambivalent It is also proved that science is based on the philosophical foundations. It is true that statements of philosophy can't result from the generalization of scientific knowledge. But it is also true that scientific knowledge can't be logically derived from some actual philosophy. The difference in logic and subject-matter between philosophy and science is the same as it is between theoretical and empirical knowledge, because these are two qualitatively different in the subject –matter levels of knowledge. But the gap between them is reducing constantly due to the constructive action of thinking aimed at the creation of corresponding schemes of interpretation. Only if philosophical interpretations of science take place, it can be the material used either for confirmation or refutation of the philosophical conceptions. But it is also true that only by philosophical interpretation can this or that kind of philosophy either affect or effect science. It is obvious that without philosophical foundations of science not only its integrity is damaged, but the integrity of culture in whole, in respect to which philosophy and science are its aspects.

VI. Conclusion

The organization of scientific knowledge of any developed sciences is vertical-level [16]. It consists of four qualitatively different levels of knowledge: perceptive, empirical, theoretical and meta-theoretical. Each of these levels has its own ontology and methodology, thus the relationships between them are constructively and interpretational.

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