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ФІЛОСОФІЯ

Володимир Іванович Кузнєцов
Головний науковий співробітник відділу логіки та методології науки,
доктор філософських наук, професор,
Інститут філософії імені Г.С.Сковороди НАН України,
4 Трьохсвятительська, Київ, 01001, Україна;
Професор кафедри фізико-математичних дисциплін,
Національний університет «Києво-Могилянська академія»,
2 Сковороди, Київ, 04665, Україна

Vladimir Kuznetsov
Principal Researcher of the Department of Logic and Methodology of Science,
Doctor of Philosophical Sciences, Professor,
H.S.Skovoroda Institute of Philosophy of the National Academy of Sciences of Ukraine;
4 Tryokhsviatitelska, Kyiv, 01001, Ukraine;
Professor of the Chair of Physical and Mathematical Disciplines,
The National University "Kyiv-Mohyla Academy",
2 Skovorody, Kyiv, 04665, Ukraine

E-mail: vladkuz8@gmail.com, kuznetsovvi@ukma.edu.ua;
ORCID: http://orcid.org/0000-0002-8193-8548
Web of Science ResearcherID O-6612-2014
Scopus Author ID: 57199931585

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MODIFIED STRUCTURE-NOMINATIVE RECONSTRUCTION OF PRACTICAL PHYSICAL THEORIES AS A FRAME FOR THE PHILOSOPHY OF PHYSICS

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Abstract

Physical theories are complex and necessary tools for gaining new knowledge about their areas of application. A distinction is made between abstract and practical theories. The last are constantly being improved in the cognitive activity of professional physicists and studied by future physicists. A variant of the philosophy of physics based on a modified structural-nominative reconstruction of practical theories is proposed. Readers should decide whether this option is useful for their understanding of the philosophy of physics, as well as other philosophies of particular sciences.

The article is written within the theme "Communicative transformations in modern science" of "Program-targeted and competitive topics of the National Academy of Sciences of Ukraine".

Keywords: practical physical theories; physical lingua franca; subsystems of theories; subsystem flexibilities; main and auxiliary components; basic and satellite levels.

Модифікована структурно-номінативна реконструкція практичних фізичних теорій як основа філософії фізики

Анотація

Фізичні теорії є складними та необхідними інструментами отримання нових знань про галузі їхнього застосування. Проводиться розрізнення між абстрактними та практичними теоріями. Останні постійно вдосконалюються у пізнавальній діяльності професійних фізиків і вивчаються майбутніми фізиками. Запропоновано варіант філософії фізики, заснований на модифікованій структурно-номінативній реконструкції практичних теорій. Читачі мають вирішити, чи корисний цей варіант для розуміння ними як філософії фізики, так й інших філософій окремих наук.

Стаття написана в рамках теми «Комунікативні трансформації в сучасній науці» «Програмно-цільові та конкурентні теми Національної академії наук України».

Ключові слова: практичні фізичні теорії; фізична lingua franca; підсистеми теорій; гнучкість підсистем; основні та допоміжні компоненти; базові та сателітні рівні.

1 Introduction

The problematic situation in the philosophy of physics is as follows. On the one hand, modern physics is inconceivable without the use and development of theories. However, physicists themselves do not usually explain what they mean by theories. [See, for example, Kompaneyets 2012; Landau and Lifshitz 1981-1986; Vakarchuk 2007]. On the other hand, many philosophical interpretations of theories have been proposed. [See, for example, Agazzi 2015; Balzer, Moulines, Sneed 1987; French 2020; Winther 2020]. However, there is no evidence that physicists use them. Indeed, the physical encyclopedias do not hold references to these interpretations. [See, for example, Flügge 1955-1984; Françoise, Naber, Tsun 2006; Meyers 2001; Prokhorov 1989-1998].

Meanwhile, an adequate description of physical theories is important for understanding the role of the philosophy of physics in the development and teaching of physics. The article is based on materials from physics and its philosophy. However, when the article mentions science in general and the general philosophy of science, it is assumed that statements about them also apply to physics and its philosophy.

2 The role of theories in science and the role of their reconstructions in philosophy of science

Mario Bunge (1919-2020) gave a brief description of the importance and functions of scientific theories in science. “A peculiarity of 20th century [and surely the next centuries – VK] science is that the most important scientific activity – the deepest and most fertile – is centered around theories rather than around stray questions, data, classifications, or stray conjectures. Problems are posed and data are gathered in the light of theories and with the hope of conceiving new hypotheses that may in turn be expanded or synthesized into theories; observations, measurements and experiments are executed not only to collect information and generate hypotheses but also to test theories and find their domain of truth; and action itself, to the extent to which it is deliberate, relies more and more on theories – for the better or for the worse. In short, an emphasis on system – on empirically testable theory, of course – rather than on raw experience is what characterizes contemporary science.

Scientific theory can be studied either as an activity or as a finished even though not final product of that activity. But it is hopeless to try to understand the dynamics of theory construction before knowing what theories are” [Bunge 2017: 446].

It is not surprising that the conceptions of scientific theories are central to the philosophy of science. Half a century ago, Frederick Suppe (1940-) stressed that “it is only a slight exaggeration to claim that a philosophy of science is little more than an analysis of theories and their roles in the scientific enterprise. A philosophy of science's analysis of the structure of theories is thus its keystone; and should that analysis of theories prove inadequate, that inadequacy is likely to extend to its account of the remaining aspects of the scientific enterprise and the knowledge it provides. At the very least, it calls for a reassessment of its entire account of scientific knowledge” [Suppe 1977: 3].

However, a natural question arises why the long-term philosophical analysis of scientific theories carried out so far has not been reflected in the works of modern scientists. Therefore, many philosophers of science are looking for new arguments in favor of the necessity of philosophy for science [Boschiero 2020; De Haro 2020; Laplane et al 2019; Rovelli 2018]. Unfortunately, their arguments are mostly about a few special episodes in the history of science in which eminent scientists testify the importance of philosophy in promoting the ideas that glorified them. The author is not aware of the attempts of philosophers of science to identify and analyze the set of necessary components of scientific theories that distinguish them from narratives. As a rule, existing attempts highlight only a few components, ignoring the rest.

After the publication of the opinions of M.Bunge and F.Suppe, many new philosophical analyses of theories were proposed [French 2020]. However, none of them received universal recognition.

Thus, one of the peculiarities of the

contemporary philosophy of science is the presence of many options for the philosophical analysis of scientific theories. In order not to confuse the metamodels of theories with models of realities studied with the help of theories, the first models will be called reconstructions. In follows I will rely on the modified structural-nominative reconstruction of scientific theories (MSNR).

The name of this reconstruction is explained by the fact that in it the components (structures) of the theory are analyzed as having definite names in a broad sense. Formal and informal versions of the named set theory [Burgin 2011] provide an apparatus for such an analysis [Burgin and Kuznetsov 1994]. Its initial variant 1) distributes various forms of scientific knowledge (models, problems, operations, estimations, etc.) across five heterogeneous subsystems of theories; 2) reveals the various connections between these forms and the appropriate subsystems; 3) promotes a defragmented understanding of the theory, within which its subsystems and components find their natural place [Burgin and Kuznetsov 1994].

Some details of MSNR will be described further. In sum, it: 1) identifies homogeneous subsystems; 2) takes into account both coordinated transformations of subsystems and their components; 3) opens up prospects for the consistent study of the development of the theory from the point of view of changing its components; 4) creates the preconditions for the scrutiny of widespread ideas about science and its development the basis of simplified reconstructions of theories (for example, K. Popper) or fuzzy sociological and historical conceptions (for example, T.Kuhn) [Kuznetsov 2018; Gabovich and Kuznetsov 2019].

3 Goals of science and goals of its philosophy

But what is the goal of reconstructions of a theory? To answer this question, it seems reasonable to distinguish the goals of physics as a science and those of the philosophy of physics as a metascience of physics.

The main goal of physicists is to study certain domains within the framework of her/his theories and gain new proven knowledge about these domains. Such knowledge describes and explains known phenomena, and is also used to predict new phenomena in the domains of theories.

One of the main goals of philosophers of science is to gain metaknowledge about the composition of scientific theories, their types, properties, functions, relationships, applications and regularities of birth, growth and death [Agazzi 2009].

Explication of this metaknowledge has cultural, epistemological, educational, cognitive and didactic significance, at least for the training of future scientists. It seems also that adequate metaknowledge about theories is not useless even for professional scientists. After all, they not only read scientific texts, but besides create original ones, which should contain new knowledge presented in a specific form. This form is determined by what they mean by theories. In any case, conscious and explicit metaknowledge about theories is better for the production, presentation and understanding of new scientific knowledge than implicit or intuitive. Any activity is carried out better if its subject adequately comprehends its tools and conditions.

If the goal of science is the production of new knowledge, then the creation of an adequate picture of its tools, that is, the scientific theories, lays a solid and reliable basis for achieving the common goal of all metasciences. This is an increase in the efficiency of the generation of knowledge through the study of all its conditions, from historical to economic. Among metasciences are history of science, psychology of science, sociology of science, economics of science, axiology of science, teaching of natural sciences, ethics of science, management of science, pragmatics of science, culture of science etc. Their specific goals include the identification and description of essential, rather than phenomenological, patterns of the development of science; analysis of the characteristics and types of scientific creativity; research of the collective and communicative nature of scientific activity; exploration of the mechanisms of interaction between society and science; determination of criteria for the economic support of science and the norms of its effectiveness; study of both the relationship between various sciences and between science and technology, etc.

4 Theoretical physics and its language

MSNR uses the so-called *physical lingua franca*[1], on which theoretical physics is really created, used, developed, and studied since its inception. Textbooks and scientific publications are written in this language[2]. The resources of this language can be used in three ways: to describe the studied realities, to construct theories about these realities, and to express metaknowledge about corresponding theories. This three-valence becomes unambiguous when the context of the use of words and expressions of this language is taken into account. For example, the referent of the term "wave function" can be such a physical reality as an electron ("electron wave function") or a mathematical construction of such a physical theory as quantum electrodynamics ("a wave function as a vector of an infinite-dimensional Hilbert space of states describing the physical states of an electron") or component of the model subsystem of reconstruction of quantum theory ("wave function as a mathematical model of the electron").

If one does not take into account the contexts of using the term, she/he can come to its identification with reality, one of the names of which this term is. Sometimes such a misuse leads to grandiose worldview consequences, as is the case in the conception of the multiverse. The interpretation of the wave function as a physical reality and its reduction into one of its possible states in the process of measuring, say, electron properties, which are described by the wave function, is added by the hypothetical assertion about the materialization of all its states in the form of the emergence of the infinite number of new non-interacting universes.

From a bird's eye view, theoretical physics is an area of productive creativity. To obtain testable new knowledge, theorists do much more than apply and develop existing physical theories. They also construct new hypothetically useful theories based, in addition to entirely new ideas, on modifications of components of accepted and even rejected theories [Gabovich and Kuznetsov 2020].

Physical theories, the network of which forms theoretical physics, are in state of a flux. With this in mind, it makes sense to distinguish between the abstract and the practical implementation of the same physical theory. Abstract theory is a systematized and stable repository of confirmed fixed knowledge about its subject area. At the same time, practical theory is an indispensable ingredient in the cognitive processes of obtaining new knowledge in its domain. To do this, it must be mutable.

Within the framework of theoretical physics, practical theories are used both in the real cognitive activity of professional physicists and in the training of future physicists. Students learn a specific practical theory not as a self-sufficient system, but as related to other practical theories. Let us emphasize that quantum theory could not have been created without classical mechanics, electrodynamics, and thermodynamics. Its teaching also presupposes a fairly substantial knowledge of these theories.

Practical theories are presented in numerous and varied expositions in textbooks, monographs, scientific articles and conference proceedings. As a sign of their development, many different textual representations of almost any scientific theory appear every year. They differ not only in details, but in many cases also in the inclusion of some new scientific advances. Due to these modifications, new generations of future scientists begin their research on the basis of the latest theoretical advances. In fact, formally oriented philosophers of physics scrutinize not practical theories, but definite reconstructions of their fragments, selected on the basis of certain axiomatic, logical, linguistic, pragmatic, aesthetic and similar preferences. A prerequisite for such

[1] The *physical lingua franca* is not the *physicalist language* introduced by the logical positivists, who demanded that both physics and its philosophical analysis be carried out in it.

[2] An indisputable empirical fact is that the presentation of the content of existing professional works and textbooks on theoretical physics does not include such popular terms in the philosophical environment as "paradigm", "normal science", "revolution", "incommensurability", "falsification", "proliferation", "hard core" and "protective belt". In contrast, philosophers also use physical terminology ("objects/realities under study", "magnitude/measurable property", "quantitative value", "computable value", "law", "model", "problem", "solution", "measurement", "approximation" etc.) when describing physics and its development.

an analysis is the consideration of an abstract theory as a static and isolated system without any changeable components.

The harsh reality of instructing science and even mathematics is that no student studies classical and quantum mechanics, genetic, chemical, number and geometric theories as abstract theories constructed in accordance with some a priori principles. Moreover, in search of solutions to unsolved problems, no active scientist resorts to formal reconstructions of abstract theories, the abundance of which is offered by the philosophy of science.

In sum, theoretical physics is the natural habitat of practical theories. In this environment, a specific theory does not exist without the use of some other theories, but competes with theories with the same domain of applicability. For example, there are many competing theories of gravity.

However, philosophers of science do not pay enough attention to reconstructing practical theories as permanently changing and interdependent systems.

5 Intra- and inter-theoretical flexibility

To be changeable and dependent on other theories, the components of practical theory must be intra-theoretical and inter-theoretical flexible.

For example, a change in a model as a component of a theory may be driven by a desire to modify radically the model. In this case, intra-theoretical flexibility is manifested in the fact that a change in the model can cause induced changes in some other components of the theory. The illustration is a reformulation of the problem that was originally posed within the original model in terms of the modified model. An example of intra-theoretical flexibility from the history of physics is a reformulation of the problem of the stability of the solar system, when the planets were modelled as interacting only with the sun. Taking into account their mutual interactions made astronomers to construct new model, rethink in its framework this problem, and introduced new mathematical methods within celestial mechanics

Inter-theoretical flexibility is found when a change in theory is caused by the use of another theory in it. For example, the successful use of new mathematical tools by practical theory often radically expands the theory domain and leads to the solution of previously unsolved problems and the formulation of new problems. Considering fragments of mathematical theories used by classical mechanics as its components, we can associate its changes, for example, with the inclusion of new mathematical concepts and operations with them in mathematical languages of mechanics. Examples are fluxions, derivatives, differential and integral calculus, differential equations, phase flows, smooth maps and manifolds, Lie groups and algebras, constructions of symplectic geometry and ergodic theory [Arnold 1989]. Each of these inclusions prompted the construction of new models, within the framework of which new problems were posed and new methods for their solution were proposed. All this expanded the domain of classical mechanics each time. There seems to be no end to the changes of practical theory such as classical mechanics.

Another example of inter-theoretical flexibility occurs when a model built within the framework of one theory leads to insoluble contradictions in it. An illustration from the history of modern physics is a reformulation of the problem of the stability of atoms, when atoms were viewed as consisting of nuclei and electrons revolving around them. This problem was posed within the framework of the classical electrodynamics model, but it was solved in the Bohr model of atoms with stationary electron orbits. In turn, this model was an impulse to creation of quantum mechanics.

6 The polysystem composition of practical theories

So, the crucial point is: What are components of a practical physical theory?

Considering the philosophy of physics as one of the metasciences about physics, one can give an Ansatz of a metascientific answer to this question in the framework of the MSNR of practical physical theories [Kuznetsov 2018]. Anyway, the building of MSNR as a philosophical model of theories is only the first step in processes of constructing the possible metatheory which domain is the network of practical scientific theories. This is the beginning, not the end, of a truly philosophical understanding of science.

Similarly, a precondition for a physical answer to the question of what an atom is is to build some scientific model of atoms. Many such models have been proposed. Each of them is the core of the corresponding physical theory, which has the limits of its applicability. The potentially endless sequence of such models and corresponding theories reflects the development and change of ideas about what an atom is.

Practical theory as a system consists of components and relationships between them. If you start by looking at practical theories, you will immediately find the following.

First, practical theory has various components.

Second, each component is complex on its own and comes with different kinds of subcomponents.

Third, any component is intertwined with others in a variety of relationships.

For example, if we take models as components of a theory, we find that there are many models in theory that are interrelated. The models themselves have a complex and varied design. They are built using the languages of theory and are used as a framework for setting the tasks of studying the modelled entities.

Fourth, it is impossible to study all these components and their interrelationships at once.

A good strategy is to divide the components into their respective subsystems and first analyze the subsystems separately, and then figure out the relationships between the subsystems at the component level.

Thus, given the real complexity of both practical theories and any of their components, one of the ways to study this complexity is to reconstruct theories as polysystems, that is, to decompose theories into their subsystems. For convenience, the name of a subsystem usually coincides with the general name of its main components. A specific subsystem includes the type of components that is *main* for it, as well as components of other types that are *auxiliary* in relation to the main components. Components of one type, which are auxiliary in other subsystems, are main in their subsystem.

7 Subsystems of a practical theory

Let us describe informally and in general terms the subsystems (SSs) of practical theory.

Metaphorically, each SS is a theory's holographic representation that focuses on the main components of this SS. Its auxiliary components act either as "material" for the main components, or as methods and rules for transforming them. For example, models are auxiliary for the problem SS, since many of its main components are formulated in terms of models of domain entities. In turn, certain problems are auxiliary for the model SS as tasks of analyzing existing models or constructing new models.

Theories differ in the degree of elaboration of their SSs. For example, at present, the model SSs of all string theories are in some sense underdetermined, since their models do not produce predictions that can be verified using modern and even designed experimental equipment. Changes in the components of any of its subsystems can provide impetus to the development of other subsystems of an existing theory. Likewise, the emergence of a new theory can begin with the formation of initial and imperfect versions of any of its future subsystems. The history of the development of any science is full of examples of such processes.

SSs have a *hierarchical multilevel* structure. For example, a specific language is part of the language SS. It has *basic alphabetical, wordy, sentential, and phrasal constitutive* levels. There are also *satellite* levels corresponding to the actions of building, connecting, transforming and evaluating basic components. These levels include rules and procedures for the actions mentioned. Figuratively speaking, these levels are the real dark matter for most reconstructions of scientific theories.

SSs, their levels, components and structures are interdependent. As a rule, a nontrivial change of any component causes the induced changes of other components. Examples of such changes are model-problem and problem-problem chains. The first ones are generated by the reformulation of existing problems in terms of new models, the second – by solving actual problem that usually has produced many formulations of new problems.

It follows from the polysystemic composition of theories that available reconstructions of theories focus on one or more SSs and identify it or them with the entire theory. Since such reconstructions do not consider the connections of the selected SSs with the rest of SSs, they create incomplete or partial images of even the selected SSs.

Let us say a few words about the theory's SS.

7.1. Ontic SS

Each practical theory has a domain of its application. At any moment in the history of a theory, its ontic subsystem includes the notions of supposed entities from its domain and the notions of their attributes (properties, relationships, states, and processes). The content of this SS (or picture of theory's domain) alters at least as a result of its experimental study. These changes cause corresponding transformations in other components of a theory. For example, the domain of elementary particle theory has changed each time with the discovery of new particles and their new attributes. One of the triggers of the progress of this theory was constructing original models of elementary particles as its new components. New models have caused changes of other components of this theory. There is also the effect of internal changes of theory on its ontic SS, as happens in the case of a confirmed prediction of new phenomena. It is assumed that prediction is the result of certain changes of the components of practical theory.

7.2 Denominative SS

Thinking about the notions of domain entities and their attributes, theorists use different kinds of entity/attribute names. The *ontic subsubsystem* of the *denominative subsystem* of the theory includes various kinds of names (labels, designations, acronyms, terms, symbols, diagrams, schemes, tables and the like), which represent in the theory entities/attributes from its domain. The ontic names of supposed entities and their attributes are borrowed from the national natural language and the *physical lingua franca.*

The theoretical subsubsystem of the denominative subsystem includes similar means of naming the internal components of a theory. Sometimes the same name denotes both the entity/attribute and the corresponding component of the theory. An example is the symbol ***F***, which represents physical force and the corresponding vector function in classical mechanics.

7.3 Model SS

Models are the main components of this subsystem. They represent those attributes of the studied entities that are important for this study. Models are "magic lenses" through which scientists using a theory see entities and their attributes from its domain.

In a first approximation, there are *verbal/visual*, *empirically informative* and *mathematical* models that unite in the appropriate *subsubsystems* of model SS.

Verbal/visual models are descriptions of entities and their attributes in terms of their ontic names. For example, Copernicus's verbal model of the heliocentric universe uses individual and collective entity names ("Sun", "Earth", "planet", "star") and the names of an entity attributes ("central position of the Sun", "planets revolving around the Sun", "circular and epicyclical forms of planetary orbits").

Empirically informative models incorporate and order the quantitative results of observations and/or measurements of the attributes of the entities involved.

Mathematical models of domain entities combine mathematical models of some of their attributes [Burgin and Kuznetsov 1993] in the form of mathematical equations. Newton's second law expresses in the form of the well-known differential equation such mathematical models of attributes of material bodies as force and acceleration (as vector functions) and mass (as a scalar constant or function).

Note, that the models have their own intra-theoretical names.

7.5 Language SS

This SS unites and orders languages that have been used by practical theory.

Contrary to the myth about one language of science, each subsystem of practical theory has many special languages that describe its main and auxiliary components. Some of these languages are descriptive, others are mathematical. Some languages are dichotomous, others are fuzzy. Mathematical languages of any physical theory are borrowed from different mathematical theories and in this sense are different. In any case, the use of mathematics in a physical theory does not turn it into a mathematical theory. See also above information about levels of a language.

7.6 Nomic SS

This SS contains formulations of laws, axioms, and postulates, representing in the theory attributes and regularities of entities from its domain, as well as the principles of organizing and changing the theory itself.

7.7 Notions of the rest of SSs

In the spirit of the above informal descriptions, it will not be difficult for the reader to get an informal understanding of the composition and functions of the rest of SSs. These are *definitional* (formal and informal, full and partial definitions both of the entities/attributes from the domain of theory and components of the theory); *ordering* (deductive, inductive, abductive, taxonomic and the like means of ordering other subsystems of the theory); *problem* (problems, questions and tasks that are formulated and solved by theory); *operational* (operations both with the components of the theory and with the theory itself); *procedural* (procedures as rules for performing actions); *evaluative* (evaluations of components and theory); *hypothetical* (plausible hypotheses taking by theory); *heuristic* (useful but not well justified heuristic considerations); *approximate* (approximations of the theory and its components) and *connecting* (connections of both subsystems and their internal components) subsystems.

I invite readers to identify and describe these subsystems in the scientific theories known to them.

Conclusion

The philosophy of any particular science, formulated in terms of a modified structural-nominative reconstruction of practical physical theories, seems to be closer to the practice of real sciences than other versions of it. The author and his colleague Alexander Gabovich plan to give in the near future, within the framework of this reconstruction, a detailed presentation of some aspects of the philosophy of physics and the philosophy of mathematics.

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