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THE STRUCTURE-NOMINATIVE RECONSTRUCTION OF SCIENTIFIC KNOWLEDGE

In this paper we propose an informal exposition of the structure approach in the philosophy of science. Scientific knowledge is here considered as a collection of scientific theories. Each scientific theory has logico-linguistic, model-representing, pragmatic-procedural, and problem-heuristical subsystems and a subsystem of ties. The pivotal methodological concept for the exact description of these subsystems is the named set. We also outline the possibility of applying the structure-nominative approach to certain problems in the philosophy of science.

I. INTRODUCTION

The understanding of scientific knowledge, its nature, patterns of development and application is essentially determined by answers to questions concerning the nature and structure of scientific theory. That is why one of the principal tasks of the philosophy of science is the elaboration of a realistic account of the properties and functions of theories (Agazzi [1981]). Constructing exact models (reconstructions) of theories is an effective tool in achieving this end. In the course of the analysis and use of such reconstructions we must obtain new information about scientific

Epistemologia XI (1988), pp. 235-254.

theories. This information has to be compatible with known data about the peculiarities, functioning and history of the development of theories. In addition, it has to predict new facts, ties and patterns concerning theories.

In any exact model of scientific theory we may pick out an informal and a formal component. The informal component includes ideas about all elements of knowledge which incorporate every advanced (mathematical, physical, chemical, biological, economical etc.) theory. The formal component included precise tools and methods used in the course of constructing and investigating the model itself. One's aim in using these tools and methods is not only to formalize the informal component, but to deepen one's understanding of it.

Concerning the informal component, the idea that a scientific theory is a very complex system is essential in the philosophy of science. But very often the analysis of a theory as a system does not take into consideration its different subsystems. Practically every such subsystem may incorporate elements from the theory. For example, a theory may be investigated as a system of concepts, as a system of propositions, as a system of laws, as a system of models of objects from its object field, as a system of hypotheses, as a system of ideal operations, and so on. The integrity of any of these subsystems is provided by its specific ties: relations of generality and specificity for concepts; deductive and independence relations for propositions; relations of specialization and theoretization for models; relations of implication for laws; relations of confirmation for hypotheses, and so forth. The formal and informal analysis of such systems provides one with a better appreciation of the role played by the various elements in a theory, and allows one to investigate the structures related to them. Some of these systems are studied informally: e.g. the theory as a system of concepts. Others require both informal and formal methods: e.g. the theory as a system of propositions (the standard conception employing the methods of mathematical logic), or the theory as a system of models (the structuralist approach employing the methods of set theory). There is also a tendency to apply formal analysis to other elements of a theory. For example, structuralists

try to provide an exact analysis of laws, considering them as subsets of potential models.

In general, we may say that a scientific theory has a polysystemic structure, i.e. every scientific theory contains interrelated subsystems.

II. THE PRINCIPAL SUBSYSTEMS OF SCIENTIFIC THEORY

If we understand each theory as a very complicated conceptual system, then the analysis of theories of modern science (and their reconstructions) exposes the following subsystems on the highest level of the theory hierarchy.

The logico-linguistic subsystem serves as a tool for the linguistic expression and logical organization of knowledge connected with a theory. *The model-representing subsystem* gives, by means of modelling the conceptual representation of objects, events, processes and their properties and the relations between them. *The pragmatic-procedural subsystem* reveals the operational nature of theory: factually all its elements are conceptual operations or means for the realization of such operations. *The problem-heuristical subsystem* discloses theory as a mechanism for posing and resolving scientific and practical problems by means of both strict and heuristic methods. *The subsystem of ties* contains different connections between previous subsystems as well as reflecting the existence of common elements in these subsystems.

One of the main tasks of the structure-nominative approach is the analysis of all these subsystems from a unified standpoint (Burgin and Kuznetsov [1986], [1987]). On the basis of this approach it is possible to unite and develop existing reconstructions of scientific theories from various perspectives. The need for such a unification and development was not evident for a long time because philosophers defined theory in terms of only a single subsystem. The rival conceptions of theory that exist provided at best an exact but incomplete picture of scientific theory.

For example, it is easy to trace the differences between classical and quantum electrodynamics, comparing their analogous subsyssystems. These theories have specific linguistic tools, such as the mathematical languages of vector spaces and spaces respectively. These theories reflect different aspects of the physical world: continuous and discrete electromagnetic processes; and these phenomena are represented by specific models: that of the classical electromagnetic field and that of the quantum electromagnetic field. Each theory contains a characteristic set of operations and transformations (in particular, quantum but not classical electrodynamics includes renormalization procedures). Lists of problems solved in each theory have common items, but they are not identical.

All the subsystems mentioned are situated on the highest level of the theory hierarchy, and in turn themselves have a hierarchical structure. We shall give an informal description of their structure and component content.

III. THE LOGICO-LINGUISTIC SUBSYSTEM

The lower (first) level of the hierarchy of the logico-linguistic subsystem contains the concepts used in a given theory. Often concepts are generated by definitions. By means of them scientists establish ties between different concepts and the linguistic forms of concept expressions, and between objects represented by the corresponding concepts.

Semiotic forms of the expressions of concepts (termini) are the elements of alphabets and vocabularies of theory languages. Usually every concept has various semiotic forms for its expression, each of which is not always synonymous in all contexts. Many scientific concepts have symbolic as well as verbal forms of expression. Alphabets and vocabularies consisting of scientific terminology, of words from natural languages, and of special symbols form the second hierarchycal level of a particular subsystem.

The third level includes the rules for constructing the expressions of a theory's languages from elements of the second level. These rules are formulated explicitly only within formal theories. Scientists use linguistic expressions for different purposes, but from a semiotic point of view expressions function as semiotic constructions naming both semiotic and nonsemiotic objects. For example, complex espressions are used alongside elements from alphabets to designate objects studied by a theory (in this case expressions function as complex names of these objects). Expressions may serve as designations of properties of objects and of relations between objects. Often they designate properties of names of objects or relations between such objects and names, in the naming of concepts and so on.

The expressions constructed out of symbols from the alphabets constitute the system which is one of the language of a given theory. As a rule each scientific theory has several languages. The fourth hierarchical level includes the set of a theory's languages. Note that these languages may be selected on the basis of different principles. The first principle is connected to an opposition between the theory and its object domain. As a result, we have what are called the theoretical and empirical (or observational) languages. The second principle is tied to the inner structure of a theory: the languages are singled out corresponding to the principal theory's subsystems. These languages include the following: 1) assertoric languages by means of which the assertions of the theory are formulated, and which are used in the logico-linguistic subsystem; 2) model languages serving for the construction of models and other elements from the model-representing subsystem; 3) procedural languages serving for the description of experimental and observation procedures and operations, calculation algorithms, mappings of interpretations and so on; 4) axiological languages used for the construction of different evaluations of elements and components of the theory; 5) erotetic and similar languages by means of which problems, tasks and puzzles connected with a theory and its applications are formulated; and 6) languages for describing the heuristical part of the theory (languages of hypotheses, ideas, heuristics and so forth).

Ties between languages are established by means of different interpretations and properties of expressions from these languages are determined by specific values. The best known and most studied of these interpretations is that of so called theoretical languages into empirical ones. It is a partial case of the interpretation of theoretical languages into texts constructed from expressions of empirical languages. The typical example of values is the establishment by formal semantics of the truth or falsity of expressions from assertoric langaugaes.

The fifth hierarchical level includes rules for transforming certain expressions into others to preserve particular evaluations. For truth-preserving transformations the best known rules are *modus ponens* and *modus tollens*.

The sixth level consists of axioms (laws) of a given theory which are represented by means of definite expressions from assertoric languages, as illustrated by the axioms of Euclidean geometry and the laws of motion of classical mechanics.

The seventh level is the result of the application of inference rules (specific transformation rules) to the axioms of a theory. That is, the element of this level are assertoric calculi consisting of axioms, rules of inference and theorems. On the standard conception of scientific theories calculi are taken as basic elements of theories (Suppe [1974]).

The eight level includes towers of calculi having the form $F_1 \subseteq F_2 \subseteq ... \subseteq F_n \subseteq ...$, where F_i is a formal calculus ($i = 1, 2, ...$) (Maslow [1986]), as well as other complex constructions of calculi by means of which processes of calculi change are described.

IV. THE MODEL-REPRESENTING SUBSYSTEM

The central function of the model-representing subsystem is to construct model representations on objects from the theory's domain. An individualization of objects from a certain field usually preceeds the construction of models of these objects. This individualization requires baptizing objects by means of words, expressions and texts from natural or artificial languages. Names (in a broad sense) of objects studied with the aid of a theory are elements of the first hierarchical level of the model-representing subsystem of the theory.

The second level within this subsystem includes the names of

certain properties and relations between the objects studied and various semiotic constructions for a representation in the theory of these properties and relations (abstract properties and relations, functions etc.). Some of the objects investigated, their properties and their relations are basic (from a particular standpoint). Their names are elements of the third hierarchical level. For instance, for the vector formulation of classical mechanics this level includes such names as "material point", "force", "acceleration" and "position".

The models of objects from the theory's domain are elements of the fourth level. By means of names, a class of modelled objects and some collection of their basic properties are represented in models. In general, a model of a given object is another (conceptual in the case of a theory) object (modelling the first object) which corresponds to the modelled object. In addition, definite properties of the modelling object describe (reflect) basic properties and relations of the modelled object.

Very often the basic properties and relations are represented exactly in a theory's models by means of functions. These functions give a qualitative or quantitative description of the objects studied and their properties. The values of certain functions are found by means of purely computational (calculational) procedures and/or by means of measurement. Functions may be defined by the means considered or by another theory. So it is possible to single out different kinds of functions and models which include these functions. For example, the social sciences as a rule use informal models that include functions which give only a qualitative picture of the reality studied. The majority of the empirical sciences use models with functions whose values are found by means of both computation and measurement. This feature of empiricial science leads to problems regarding the relation between theory and experiment.

Among models constructed using the conceptual tools of the theory, i.e. its possible full models, an important place is taken by models whose functions have such relations as corresponds to the theory's laws. These models are elements of the fifth hierarchical level of the model-representating subsystem. On this level each law is represented by some set of models. The sixth and seventh levels include laws of second and higher orders. As examples we mention invariance principles, supersymmetry principles, probabilistic laws and so on.

It follows from the above that the model-representing subsystem has a complex structure since it depicts objects from a theory's domain with their properties and properties of these properties, properties of ensembles of objects, dynamic, static and statistical regularities of objects and so forth.

V. THE PRAGMATIC-PROCEDURAL SUBSYSTEM

This subsystem is naturally divided into two parts of the lower levels of the hierarchy. One of them is called the operational subsystem and consists of descriptions of cognitive actions and operations that are represented by conceptual structures of this kind, such as methods, algorithms, and procedures (of naming, deduction, abduction, abstraction, generalization, model construction, evaluation, problem solving etc.). Each cognitive action is considered as a primitive element comprising a cognitive activity. On this account a cognitive process as part of a cognitive activity appears as a partially ordered system of actions (operations) having in the most cases a beginning and an end.

Since a function is viewed as a tie between certain elements, it may be realized as an operation that consists either of a single integral action or of a process establishing this tie. An operation's having such integrity does not exclude its being incorporated into another operation or a composite structure of some operation. But this fixes our attention on operational unity. We take the operations of the addition and multiplication of natural numbers as examples. While for single digit numbers these operations are very simple and may be considered as single actions, the same operations for many digit numbers are complex and include many additions (and multiplications) of single digit numbers. Another example of operations appears in mathematical logic where logical connectors and different quantifiers define operations on sets of

propositions and predicates.

A second part of the pragmatic-procedural subsystem incorporates axiological components. The axiological (evaluating) part includes various evaluations depending on the norms and ideals adopted for actions, operations, algorithms and all the other elements and components of a theory (including perhaps even the whole theory). Now the evaluation that has been most explored is the application of truth to propositions and their transformations. This evaluation has the values "TRUE" and "FALSE". Additionally, to assess operations constructivity and realizability are used, to assess procedures effectivity and complexity are used, to the methods heuristicability and rationality are applied, to problems originality and simplicity are applied, solutions of problems are assessed in terms of validity and universality, models are assessed in terms of adequacy and beauty, and so on. All evaluations are represented by abstract properties (Burgin [1985]).

The concepts of operation, procedure, property and evaluation are basic to the pragmatic-procedural subsystem. They specify all the hierarchical levels of its parts, namely the operational and axiological levels. Those levels, like the ones in the logico-linguistic subsystem, contain rules for the composition of operations, procedures, properties and their specific case -- evaluation, algebras and the calculi of such entities, their classes, and so on. On the higher levels of the pragmatic-procedural subsystem must be situated deontic logics and logics of action. But such logics are only beginning to be investigated (von Wright [1981]), and no real theory has such components as explicit elements.

VI. THE PROBLEM-HEURISTICAL SUBSYSTEM

In modern science it is impossible even to formulate problems and cognitive tasks, or introduce hypotheses and ideas not treating of the solving of problems or the verification of hypotheses, outside of scientific theories. That is why any sufficiently complete methodological reconstruction of theories must also include such forms of knowledge and cognition. So these forms are united in the problem-heuristical subsystem of a theory. This subsystem, like the previous one, is divided into two parts: one dealing with problems, and the other with heuristics.

The basic elements of the problem part are problems, tasks and questions which specify all hierarchical levels of this part. But the main component is the concept of a problem. It is introduced by a situation in which some object (real or ideal, like knowledge) is absent. At the same time a subject who is connected in some way with this situation possesses knowledge about this absence and an intention (desire, tendency, obligation, purpose and so on) to eliminate it. When an absent object is of a material nature the problem first appears in the form of a task demanding the finding or construction of this object. Thus the original problem concerning the space shuttle comes out as the task of creating it. When an absent object is particular information the problem may take the form of a question as well as a task which, in contrast with previous kinds of task, may be called cognitive. From this point of view a question is an interrogative form of a problem when only the problem situation is fixed. At the same time a task is an intentional (in particular, an imperative) form of cognitive problem demanding that some action be directed towards finding the absent information.

On the next hierarchical level of the problem part appear specific auxiliary linguistic tools such as the interrogative words "how", "what", "why", "when" and so forth. The symbolic representations of these elements form alphabets of the languages of the description, modelling and calculation of questions, tasks and problems. The simplest formal structures that are used for task modelling in calculi are symbols of some alphabet (Kolmogoroff [1932]) and formulae of the usual logical languages which have interrogative semantics (Ershov and Samochvalov [1984]). On the higher levels of this subsystem are situated different calculi and algebras of tasks, questions and problems.

VII. THE SUBSYSTEM OF TIES

The subsystem includes different ties and connections between elements, levels and components of the subsystems discussed above. Thus, the semantics of assertoric languages is defined by models from the model-representing subsystem. So this semantics connects elements from the logico-linguistic subsystem with elements from the model-representing one. Further, as all outer objects in a theory domain are represented in the domain by their models, problems concerning the investigation of these objects can only be solved using models of them. Solution processes as elements of the pragmatic-procedural subsystem tie together the problem-heuristical and the model-representing subsystems.

VIII. THE CONCEPT OF THE NAMED SET AND THE MATHEMATICAL MODELLING OF SCIENTIFIC THEORIES

A precise description of the hierarchical types of a theory, of their levels and elements, of relations between them and corresponding processes of change and development is achieved by the use of the principles of the *named set theory* (Burgin [1984]). It is important to note that in this theory a name is understood in a way that is significantly more general than is usual. As symbol constructions, names in this theory may be attached to practically any objects: real entities and their properties, separate symbols, denotations, denominations, descriptions, definitions, models etc. Such names are not considered to be isolated but to be connected with other entities that they baptize. In the context of scientific theory we can take as such entities objects from the theory's domain, properties of these objects and relations between them, properties of properties, processes within and between these objects, symbolic models of objects, experimental operations with these objects, and so on. As a rule precisely the same elements of a theory in some cases play the role of names while in other cases they are entities that are baptized by other names. Thus in the model-representing subsystem the models are used as specific names for the objects studied while in the subsystem of ties the same models appear as entities named by other symbolic constructions (separate symbols, expressions, texts) from the logico-linguistic subsystem. Some elements are sometimes used as names of themselves – for examples the self-referential usage of words such as in the question "How does one write the word 'self-referential'?".

The concept of a named set functions within science to unify objects and their names. Informally, a named set **X** is a triple **X** = (*X*, α, *I*) where *X* (a support of **X**) and *I* (a set of names of **X**) are sets (or classes) from some fixed classes and α (a naming relation of **X**) is a relation between *X* and *I* (a function from *X* to *I*) that belongs to a chosen class of relations. In the *named set theory* a number of important notions are introduced. They explicate kinds of named sets, rules that determine operations over named sets, transformations of named sets and so on. Among them are a named subset of a named set, a morphism (map) of named sets, left, right and inner extensions and coextensions of named sets, and named sets of higher orders. Note that "usual" and fuzzy sets, multisets, fibres and many mathematical and logical structures are special cases of named sets.

By means of the *named set theory* any element of scientific theory may be modelled and precisely analyzed. This is achieved by applying to it, as its mathematical model, a definite system of named sets tied to one another. This system explicates and makes more precise static and dynamic properties of these elements, the relations between them and the laws they obey. For example, a concept has many sides or aspects: its meaning, extension, role, and so on. Each of these aspects may be analyzed as a specific named set which has own name. If we consider the named set modelling extension of a concept, then a set of names of this named set consists of different symbolic forms of concept explication, such as the words of natural languages, and symbols and expressions of artificial languages. The support of this named set is a collection of entities united by this concept. The naming relation is fixed if the usage of these names is correct as to the entities that are explored with the help of the concept considered. Additionally, named sets expressing the sense, role, situational meaning etc. of a concept may be applied to it. Such mathematical modelling makes it possible to study connections between the concept's different sides and functions, its relations with the other elements of a theory, the laws of concept formation and functioning and so forth (Burgin and Kuznetsov [1986]).

In explicating senses, contents and interconnections of problems different conceptual structures are applied. Any such application σ is connected with a named set of corresponding semantics having the form (*Z*, σ, Str), where *Z* is a set of problems and Str is a class of conceptual structures. The simplest examples of such an application give us formulations of problems by means of natural languages or by means of the linguistic tools of a scientific theory. Depending on the nature of these structures it is possible to separate procedural, processional, object, functional, final, goal (teleological), norm, sense and other semantics of problems. In their turn any these admits further stratification. Thus sense semantics may be linguistic (texts in natural languages), logical (formulae of some logical language), graph-schemes, block-schemes and so on.

To any operation *A* a named set *A* = (*X*, *a*, *Y*) is applied with a view to the analysis of *A*. Here *X* is a set of objects on which this operation is acting, *Y* is a set of objects that may be the results of this operation, *a* is a mapping (possibly many-valued) that is realized by this operation, *A* is a name of the operation and at the same time a name of the corresponding named set.

The whole of the structure-nominative analysis of scientific theories includes as an important stage the detection of a branched and hierarchically organized system of different named sets modelling elements, ties, components, and subsystem of the scientific theory as developing structures. On the one hand its use allows one to evaluate the merits and shortcomings of current methodological approaches in the philosophy of science, and on the other this analysis may be more complete than previous attempts when it comes to the exploration of the history of science.

IX. ANALYSIS OF DIRECTIONS IN MODERN PHILOSOPHY OF SCIENCE FROM THE VIEWPOINT OF THE STRUCTURE-NOMINATIVE RECONSTRUCTION

As a first approximation it is possible to divide existing reconstructions of scientific theories into those that use precise methods and tools and those that limit themselves to only informal ideas. But in each kind of reconstruction attention is mainly focussed on an analysis of only one side of scientific theory.

So the standard approach (Suppe [1974]) that uses methods of mathematical logic in reality limits itself to a precise description and study of only some of the important elements and structures from the logico-linguistic subsystem. Note that some new achievements in mathematical logic such as calculi towers (Maslow [1986]) permit one to discuss dynamic aspects of elements and structures using this approach. The structuralist approach based on set theory mainly analyzes components of the model-representing subsystem of scientific theories (Balzer [1982]; Balzer, Moulines and Sneed [1987]; Sneed [1971]; Stegmüller [1979]). In unifying the standard and structuralist views the approach of D. Pearce and V. Rantala [1983] uses methods of classical logic and model theory. But these authors limit their investigations to a study of certain connections between the logico-linguistic and model-representing subsystems. The problem approach using erotetic logic concentrates on certain levels of the problem-heuristical subsystem (Laudan [1977]; Sintonen [1984]).

At the same time even for separate subsystems of the higher hierarchical levels each approach neglects rather important elements of scientific theories. Thus the standard approach pays no attention to the strict analysis of concepts. The structuralist view misses the existence in advanced scientific theories of computable functions side by side with measurable ones. Also laws of higher order are almost completely neglected. The problem approach does not separate problems, tasks and questions, does not connect problems with the languages in which they are formulated and with models, and so forth. Limited to a single subsystem of a theory, each approach fails to "note" or to examine to a full extent ties of this subsystem with other ones.

There are different concepts of the development of scientific theories in modern history of science. Most of them are informal. The structure-nominative analysis compares the relationship between alternative approaches, and shows what theory subsystems are central in this or that historical conception.

For example, the themes of G. Holton and the research programmes of I. Lakatos define laws of scientific development corresponding to these approaches. They show what sequences of stages in the development of a scientific theory are allowed (selected) by a given theme or a given research programme. From the viewpoint of the main subsystems of scientific theory the themes are formulated in assertoric languages, i.e. in the principal languages of the logico-linguistic subsystem, while the research programmes are represented by means of the language of problems, questions and hypotheses from the problem-heuristical subsystem.

The paradigm of T. Kuhn imply another law in his conception of scientific development. This law states that in science the process of creating new elements by analogy with chosen (paradigmatic) elements plays an important role in the form of norms or ideals. Let us note that practically any scientific element may be taken as a paradigm. Such a situation consequently leads to a mixture in understanding and interpretation of paradigms. The structure-nominative approach makes it possible ; explicate an invariant content of this concept, connecting it with the concept of a second order law (Burgin and Kuznetsov [1986]).

Even such a brief analysis shows the need for closer interaction between historic-scientific and logico-methodological reconstructions of science. At present not all aspects of scientific development explicated by the history of science have received strict and precise description in exact philosophy of science. In their turn not all models of scientific theories constructed in the philosophy of science are used in the history of science.

X. THE STRUCTURE-NOMINATIVE APPROACH TO THE HISTORY OF SCIENCE

Giving a more complete picture of the inner structure of scientific theory, and explicating its inner and outer ties, the structure-nominative approach may be taken as a basis for obtaining a clearer and more accurate insight into the historical process of scientific development.

Thus, the structure-nominative approach isolates different types of scientific development. Their evaluation must be carried out taking into consideration the fact that theory development is realized through changes and transformations of its elements and subsystems. In a theory it is possible to separate at least three types of transformations. The first type is connected with changes limited by a particular hierarchical level of the main theory subsystems. Thus we can speak about the improvement of systems of symbols, and the development of concepts, models, operations, and problems etc. This type of change is most frequently an object of historical investigation. In this case most attention is paid to the analysis of ideas and concepts of the science being studied. Significantly, less attention is paid to such history of science as takes into account processes involving the construction of models, the invention of new operations, the introduction of new evaluations, and the setting of original problems.

The second type of transformation is connected with a movement in the hierarchy of only one of the main (upper) subsystems of a scientific theory, as illustrated by processes in the logico-linguistic subsystem. Very often scientific theories are studied only within this subsystem – the whole theory is identified in this case with some part of the logico-lingusitic subsystem. From this viewpoint a history of some period of scientific development looks like a process of symbolization, formalization, mathematization and axiomatization. Other subsystems of a theory are only cursorily investigated. But the importance of processes in these subsystems becomes clear if we recall the role and meaning of experimental methods of analysis, mathematical modelling, the algorithmization of cognitive actions and so forth for the development

of modern science.

The third type of transformation reflects that in this or that period in the history of science a priority development is connected with different main subsystems of a theory. For example, in ancient Babylon the most developed was the pragmatic-procedural subsystem of mathematics, while in ancient Greece it was the logico-linguistic subsystem. Under the influence of computerization an intensive development of the pragmatic-procedural subsystem is presently taking place. Attempts are being made to formalize the problem subsystem. This is why an historical-scientific analysis of theories depending on a study of their transformations must not lose sight of the historical character of the notion of scientific theory.

XI. CONCLUSION

An adequate representation of the nature, elements and functions of scientific theories studied statically as well as dynamically is useful for a more complete and deeper understanding of theories. This study is principally important for a solution of a great many philosophical and historical problems. The structure-nominative approach provides the possibility of combining the breadth of informal analysis with the depth of a formal approach.

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LA RICOSTRUZIONE STRUTTURALE-NOMINATIVA DELLA CONOSCENZA SCIENTIFICA

Riassunto

Ci proponiamo con questo articolo di fornire un'esposizione informale dell'approccio strutturale-nominativo nella filosofia della scienza. La conoscenza scientifica viene considerata come una raccolta di teorie scientifiche. Ciascuna di esse possiede sottosistemi che hanno caratteri logico-linguistici, rappresentano in termini di modelli, hanno natura pragmatico-procedurale, risolvono

problemi e, infine, sottosistemi che collegano gli altri tra loro.

Il sottosistema logico-linguistico fornisce i mezzi affinché la teoria scientifica funzioni come uno strumento descrittivo per la rappresentazione e l'ordinamento della conoscenza. Esso si dipana su diversi livelli di gerarchia: 1) concetti espressi dalle varie strutture; 2) termini che costituiscono i nomi dei concetti, oltre ad alfabeti e vocabolari; 3) regole di costruzione per le espressioni; 4) famiglie di linguaggi (assertori, basati su modelli, algoritmici, erotetici, ecc.); 5) regole di trasformazione per le espressioni (deduttive, di calcolo, ecc.); 6) gli assiomi (leggi) della teoria; 7) calcoli diversi; 8)insiemi di calcoli.

Il sottosistema che rappresenta in termini di modelli viene usato per presentare la realtà esterna nella teoria scientifica. Esso possiede almeno i seguenti livelli gerarchici: 1) nomi di oggetti esterni, eventi e processi studiati dalla teoria; 2) proprietà astratte di tali entità); 3) alcune proprietà di base definite da un certo punto di vista; 4) vari tipi di modelli per gli oggetti esterni: sperimentali, potenziali, di misurazione, ecc.; 5) leggi di diverso livello e grado (leggi "ordinarie" e probabilistiche, leggi di limitazione, principi di simmetria e supersimmetria, ecc.).

Grazie al sottosistema che risolve problemi una teoria scientifica serve come mezzo per porre e risolvere i problemi scientifici usando sia metodi esatti che euristici. I suoi diversi livelli gerarchici sono formati da sistemi di problemi, domande, obiettivi ed ipotesi; da famiglie di linguaggi per la loro rappresentazione e descrizione; da algebre e calcoli di problemi, ipotesi, ecc.

Il sottosistema pragmatico-procedurale è composto da una parte operativa e una assiologica. La prima include come elementi espressioni concettuali di differenti operazioni, algoritmi, procedure, ecc. La seconda comprende differenti valutazioni delle proprietà e delle qualità dei componenti teorici e degli oggetti inclusi nel dominio della teoria. Anche queste parti possiedono una complessa gerarchia.

Il sottosistema delle relazioni, infine, mette in luce i vari e numerosi legami che sussistono tra gli altri sottosistemi.

L'approccio strutturale-nominativo studia una teoria scientifica ricorrendo alla teoria degli insiemi nominati. Tali insiemi possono essere "ordinari", "vaghi" (fuzzy), ecc. Schematicamente, un insieme nominato X è una tripla X = (X, α, I) dove il supporto X e l'insieme dei nomi I sono insiemi (o classi) tratti da qualche classe determinata, e la relazione nominale α è una relazione tra X e I che appartiene a una classe scelta di relazioni.

Un'analisi delle teorie scientifiche e delle loro ricostruzioni metodologiche mostra che gli elementi di base, le operazioni e le procedure ivi usate possiedono una struttura insiemistica. Pertanto una teoria scientifica considerata nel suo complesso può essere rappresentata mediante un sistema complesso e a molti livelli di insiemi. Le ricostruzioni metodologiche esistenti delle teorie scientifiche si differenziano a seconda dei sottoinsiemi che esse distinguono ed analizzano al loro interno. Sottolineiamo anche il fatto che l'approccio