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# Variables of Scientific Concept Modeling and Their Formalization

## 1. A Concept and Its Variables

There are no universally adopted answers to the natural questions about scientific concepts: What are they? What is their structure? What are their functions? How many kinds of them are there? Do they change? Ironically, most if not all scientific monographs or articles mention concepts, but the scientific studies of scientific concepts are rare in occurrence.

It is well known that the necessary stage of any scientific study is constructing the model of objects in question. Many years logical modeling was dominant in the concept studies. Last decades, concepts came to be regarded as the subject of mathematical modeling. However, different authors take different features of concepts as independent variables of their models.

Our objective is to characterize informally the spectra of relevant variables for the modeling of scientific concepts.

Any scientific concept *C* is a component of the appropriate scientific knowledge system *S*. For example, the quantum-mechanical concept **ELECTRON(QM)** differs from the quantum-field concept **ELECTRON(QFT)**. It means that $C = C(S)$. In turn, any *S* includes many components $s_1, \ldots, s_n$. Examples are symbols, constants, mathematical constructions, abstract models of various kind, equations, methods, procedures, problems, estimations etc. Characterizing a concept *C* in the frame of *S*, a scientist uses some subsystem *Ss* consisting of these components. In limiting case, *Ss* can include one component. All versions of the physical concept **ELECTRON** use the standard symbols *e* and *m*. Its non-relativistic quantum-mechanical versions use symbol ψ and various equations like the Schrödinger equation. It means that $C = C(S, Ss)$.

Because any *C* is a concept about some group of real or imaginary entities *E* from the domain *D* under study, *C* depends on both *E* about which this concept is and *D* to which *E* belongs. Any quantum mechanical versions of the concept **ELECTRON** are about the physical constituents of matter named ‘electrons’ that in classical and quantum electrodynamics are considering as source of electromagnetic fields.

In turn, the concept *C* imposes a specific representation of members of *E* and the domain *D*. We will call these kinds of interdependency, correspondingly, 'concept-entities' (*CE*) and 'concept-domain' (*CD*) links. It gives four variables of *C*: *E, D,* (*CE*) and (*CD*).

There are also five other concept variables. To 'see' them we ask the following questions. Are the entities *E* (*D*) and the relevant knowledge system *Ss* (*S*) cognitively interdependent? The answer is positive for any pairs, the first member of which is *E* (*D*) and the second member is *Ss* (*S*). Indeed, what we think *E* (*D*) is *depends on* our knowledge system *Ss* (*S*) and, vice versa, the *E* (*D*) *conditions* the nature and, consequently, composition and properties of *Ss* and *S*. These variables will be called, correspondingly, 'entities-system' (*ES*), 'entities-subsystem' (*ESs*), 'domain-system' (*DS*) and 'domain-subsystem' (*DSs*) links.

The last variable is 'entities-domain' (*ED*) link. Its incorporation is motivated by inclusion of *E* in the appropriate *D* and by determining *D* by *E.*

As a result, we have the next presentation of *C*:

*C* = *C*(*E, D, Ss, S,* (*CE*), (*CD*), (*CSs*), (*CS*), (*ED*), (*ESs*), (*ES*), (*DSs*), (*DS*), (*SSs*)).

This concept modeling is a generalization of triplet concept modeling [1].

The inspection of existent concept models demonstrates that they *necessarily* refer to *E* and *Ss* as well as *optionally* refer to some of other variables of *C*. Sometimes, analysts identify a concept with its different variables. For instance, in literature there are identifications of a concept with a general name of *E*; with *E* to which *C* is supposed to be applied; with a distinctive feature/property of *E,* etc.

Variables of *C* may be ordered in a form of *K*-pyramid. Its apex is associated with the concept *C*. Four apexes of its base are associated with entities *E*, domain *D*, knowledge system *S* and subsystem *Ss*. These five generative variables give birth to ten generated variables (interrelationships) represented by edges of *K*-pyramid and diagonals of its base. The *K*-pyramid can by used for visualizing some features of processes of concept formation, elaboration, and change.

The separation and description of components and structure of generative and generated variables are relative to the reconstructions of the scientific knowledge systems *S's* and to ontological commitments concerning the domain *D's.*

## 2. Formalizations of Concept Multiplet Decomposition

Different available reconstructions of scientific knowledge systems have invoked specific types of scientific concept models. Let us sketch the fundamentals of the abridged concept multiplet modeling by means of resources of the structure-nominative reconstruction [2]. According to this reconstruction, *Ss* contains names, including mathematical symbols, different informal and formal descriptions (especial sequences of sentences) of entities from *E,* abstract properties and relations of *E* and other entities associated with it, various kinds of abstract models of *E*, law-like statements about *E*, etc.

*Definition*. The potential particular triplet model *MOD*(*C*) of the concept *C* is a triple <*ColC*(*E*), *ColC*(*ESs*), *ColC*(*Ss*)>.

The collection *ColC*(*E*) includes entities both falling under *C* (i.e. entities from *E*) and entities associated with *E*, the set of properties of relevant entities, the set of relations between entities, the set of measurable values of quantitative properties, etc.

The collection *ColC*(*Ss*) includes sets of various subsystems (including mathematical ones) of the appropriate *scientific* knowledge system *S* used for the profound and deep representation and the effective processing of information on entities, about which concept *C* is. Among these subsystems are letters (symbols), expressions (formulas), texts (mathematical structures), mathematical models, abstract properties, structure-nominative models, etc.

The collection *ColC*(*ESs*) includes sets of operations and procedures (naming, abstracting, idealizing, observation, measurement, computing, interpretation, etc.) that concatenate, bring together the entities *E* and the subsystems *Ss*.

For example, the extensional approach models a concept *C* as a set of entities subsumed under *C*. The triplet decomposition of this model means that *ColC*(*E*) is identical to the set of entities *E*, *ColC*(*Ss*) includes general name of *E* entities and singular names for each of them, *ColC*(*ESs*) consists of operations of correct attaching general and singular names from *ColC*(*Ss*) to members of *ColC*(*E*).

1. Kuznetsov, V. 2004 "On Representing Relations between Physical Concepts", *Communication and Cognition* 37, 105-135.

2. Burgin, M. and Kuznetsov, V. 1994 "Scientific Problems and Questions from a Logical Point of View", *Synthese*, 100, 1-27.