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Problems in the System of Scientific Knowledge†

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Abstract: Problems play a crucial role in science. However, to correctly understand this role, it is necessary to have an adequate model of scientific knowledge. Here we use the most advanced and complete model called the modal stratified bond model of comprehensive knowledge systems. According to this model, problems are a specific kind of knowledge called erotetic knowledge generating the extensive erotetic system (modality) of scientific knowledge. Here we give a brief exposition of this system analyzing properties and aspects with the aim to determine the best form of problem description.

Keywords: problem, theory, science, system, modality, scientific theory, information

1. Introduction

To properly figure out the place and role of problems in science, it is necessary to use a scientific/mathematical model of the system of scientific knowledge. Only such a model can provide means for exploring important problem traits and functioning, interaction of problems with other elements of scientific knowledge and influence of problems on the development of science in general and specific scientific fields, in particular. Here we are mostly interested in problems in and related to information science as representatives of a special type of knowledge, which called *erotetic knowledge*.

The most widespread image of scientific knowledge that people have is a collection of statements about studied objects, processes and phenomena. This image was formalized and studied in the *standard model* (also called the *positivist model*) of a scientific theory, which utilized the logical dimension to represent a scientific theory as a system of propositions (cf., for example, [1,2]).

Another popular approach to description of the scientific theory structure was the *structuralist model* (*reconstruction*) of a scientific theory, which used the set-theoretical dimension to represent a scientific theory as a system of models of the theory domain (cf., for example, [3,4]).

These and other approaches in methodology of science were unified in the *structure-nominative model* of a scientific theory, which gave a four-dimensional knowledge representation including the logical and set-theoretical dimensions [5-7].

The further development of the structure-nominative model of a scientific theory brought forth the most advanced is the *modal stratified bond model* of comprehensive knowledge systems, which encompasses the structure-nominative model and provides a nine-dimensional knowledge representation [8]. In this context, advanced scientific theories are examples of comprehensive knowledge systems. Three of these dimensions, which are related to problems, are analyzed in the next section.

2. Erotetic systems as intrinsic components of comprehensive knowledge systems

At first, let us define a problem.

A *problem* is absence of something, e.g., of knowledge or information, and explicit representation of this absence.

The place of scientific problems is determined by models of scientific knowledge. The modal stratified bond model of scientific knowledge as a whole is stratified into several subsystems forming three *epistemic directions* - the modal, systemic and hierarchical directions.

The *modal direction* (*stratification*) of scientific knowledge contains three classes:

- *Assertoric knowledge* consists of epistemic structures with implicit or explicit affirmation of being knowledge, such as theorems, propositions and lemmas.
- *Hypothetic* or *heuristic knowledge* consists of epistemic structures with implicit or explicit supposition that they may be knowledge, such as conjectures and hypotheses.
- *Erotetic knowledge* consists of epistemic structures that express lack of knowledge, such as problems, questions and dilemmas.

For instance, according to the modal stratification of scientific knowledge [8], the horizontal structure of each subsystem of an advanced knowledge system, e.g., the logic-linguistic subsystem of a scientific theory, which includes the descriptive knowledge of this theory, has the form presented in Figure 1.

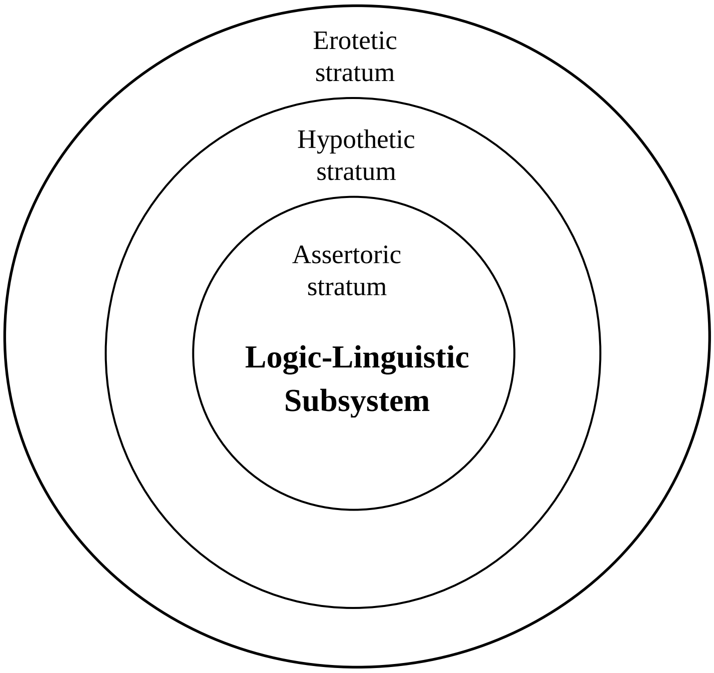

Figure1. The modal stratification of the logic-linguistic subsystem of scientific knowledge

The *hierarchical direction* of scientific knowledge comprises three levels:

1. The *componential level*
2. The *attributed level*
3. The *productive level*

The *systemic direction* of scientific knowledge is differentiated into three categories:

- *Descriptive knowledge*
- *Representational knowledge*
- *Operational knowledge*

As we can see, various types and kinds of problems form the erotetic system (stratum or modality) of scientific knowledge with respect to the model direction. Two other epistemic directions – systemic and hierarchical – disclose the structure of the erotetic system and the place problems in it. Namely, we have the following components of the erotetic system:

- *Descriptive knowledge* develops different forms of concepts and terms on the componential level, utilizes erotetic languages and grammars on the attributed level and employs erotetic logical calculi and logical varieties [8] on the productive level.

– *Representational knowledge* constructs various forms of properties and names for problems on the componential level, elaborates a variety of models of problems on the attributed level and employs systems of models for problems on the productive level.
– *Operational knowledge* builds various operations and scales for problems on the componential level, elaborates a variety of algorithms, procedures, automata, estimates, measures, norms and values on the attributed level and employs operational and assessment algebras and calculi on the productive level.

Going in the systemic direction, we see that a problem must be described in some language. There are three basic forms of such descriptions:

- A *question* explaining what is absent and requiring the absent essence
- A *task* explaining what is absent and instructing to get (obtain) the absent essence
- A *conjecture* tentatively describing the absent essence

As an example, let us consider three forms of the following problem:
Question: *What is the comprehensive definition of information*?
Task: *Construct or find the comprehensive definition of information*.
Conjecture: *The general theory of information gives the comprehensive definition of information*.
The representational knowledge related to this problem includes the meaning of terms:

– The meaning of the word *information*
– The meaning of the word *definition*
– The meaning of the word *comprehensive*

In turn, the meaning of the word *information* includes existing definitions and descriptions of information and related phenomena; usage of the word *information* now and in the historical perspective; and relations of the notion of information to other notions and concepts.

The representational knowledge related to this problem also includes relations of this problem to other problems, for example, relations to the problem of adequate measuring information.

The operational knowledge related to this problem includes different operations demanded to solve this problem. For instance, at first, it is necessary to use operations of construction or/and search. After some linguistic expression is found, it is necessary to show (prove) that it a definition and not only some description. The next step includes operations of demonstration (proving) that this is a definition of information. The next step includes demonstration (proving) that this definition of information is comprehensive. The last step demands analysis of a variety of different approaches and directions in information theory. Many of them are described in [9] but there are even more.

Unfortunately, there is a negative tendency in information studies when researchers take only Shannon's theory of communication (information), demonstrate that it does not represent many types and kinds of information and then suggest their own definition, or more often, a description of information. This situation represents the straw man fallacy.

All this gives only the first approximation of the structure of problems. To obtain a more exact and detailed structure of problems, it is necessary to use the hierarchical dimension and take into account existing types of operational knowledge. However, when a problem is formulated for experts in some area, many parts of its structure remains implicit because it is implied that experts understand them. It is possible to find more information about these structures in the book "Theory of Knowledge" [8].

3. Problem structure and its presentation

In addition to forms of problems, we analyze the structure of problems with the goal of development models for representation articles in the problem book. The extended problem structure spans in three directions (dimensions):

- The *temporal problem dimension* reveals the history of the problem, its current standing and its projection on the development of the scientific field.
- The *relational problem dimension* reflects relations of the problem to its domain, associated problems, as well as to other elements of scientific knowledge, such as theorems or procedures, and other fields of knowledge and domains of reality.

- The *innate problem dimension* describes essential properties, traits and parameters of the problem.

For instance, the problem *What is a comprehensive definition of information*? is related to such objects and systems as the diversity of information circulating in society (a part of the problem domain), to the associated problem of finding an adequate definition of knowledge, to algorithms, procedures and information processing systems, and to physics, biology and psychology.

A solution of a problem is an important element of the innate problem dimension for any problem. Thus, when problem is formulated, it might be useful to describe desirable and expected properties of the problem solution. However, it is necessary to understand that some problems have easily identifiable solutions while solutions of other problems can be vague and uncertain.

The form of a problem is an important property of this problem. Another important property is its complexity. For instance, complexity of mathematical problems is studied in [10], while complexity of algorithmic problems is studied in [11].

The analysis of the problem structure allows developing a tentative format of articles representing problems in the future book "Gothenburg Book: A Compendium of Problems in Information Studies", the primary goal of which is to stimulate the further development of information science, organize its functioning on sound foundations and create means for its better application and utilization.

Thus, it is possible to suggest three types of problem exposition (representation) in the book:

1. *Pure problem*
2. *Annotated problem*
3. *Expanded problem*

Pure problem exposition must have three basic components:

1. The Name of the problem (It may coincide with the problem Description)
2. The Name of the problem author(s), or in general, identification of the problem source
3. The problem Description (verbalization)

At the same time, pure problem exposition can include other materials related to the problem.

Annotated problem exposition has the following components:

1. The Name of the problem (It may coincide with the problem Description)
2. The Name of the problem author(s), or in general, identification of the problem source
3. The problem Description (verbalization)
4. Explanation of the terms used in the problem Description
5. Existing sources (if any), where this problem is considered
6. Other considerations related to this problem

It is also possible to suggest the following structure for an *expanded problem exposition*.

1. The Name of the problem (as the title)
2. Author(s) who is (are) suggesting this problem
3. The problem Description (verbalization) and analysis
4. Origin of the problem and the history of approaches to its solution
5. Contemporary state (Research related to the problem)
6. Desirable and/or expected properties of the problem solution
7. Relations to other problems
8. Relations to other scientific and/or practical domains
9. General remarks
10. References and bibliography on the problem

The author of the problem can also include other materials in such a text.

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