Model-Based Scientific Explanation

Ping Li (hsslip@zsu.edu.cn)
&
Dachao Li (dachao_sandy@yahoo.com.cn)
Department of Philosophy, Sun Yat-Sen University
135 Xingang Xi Road, Guangzhou, 510275 P.R. CHINA

This paper argues for the claim that scientific explanation is model-based reasoning, and makes an attempt to provide a cognitive account for model-based explanation in the framework of mental modeling (Nersessian, 2002).

Explanation is one of the most typical and important functions of scientific theories, and the D-N model of scientific explanation is one of the most valuable historical legacies of logical positivist philosophy of science. From the recent literature, a novel idea emerges: many forms of mental representations can be used to produce explanations and thus to lead to the feelings of understanding (see Brewer 1999 for a short review; and Brewer, Chinn, & Samarapungavan 1998 for a psychological explanation of explanation). Accordingly, it is possible to develop a psychological account that expounds the cognitive basis of scientific explanation.

Scientific explanation as model-based reasoning is a kind of goal-guided cognitive processes. Goals, derived from specific cognitive tasks, play an important role in determining what kinds of modeling constraints need to be abstracted from an explanandum and which levels of explanations should reach. We divide the complex forms of mental representations of scientific knowledge into three suitable levels: instance, schema, and theory, which can produce three basic levels of explanations respectively. In fact, most discussions on the representational forms of conceptual structures in the current cognitive-historical analyses of science focus on schematic models and theoretical models (e.g., mental models discussed in Gentner & Stevens, 1983). Schematic models provide explanations at the law-like level, as Brewer says: "schemata are the forms of mental representation that are appropriate to account for laws in the psychology of science and for the large class of empirical generalizations in nonscientists." (Brewer 1999, p.496)

According to the model of explanation as model-based reasoning, there are four basic steps of cognitive operations in a process of model-based explanation: (1) generic abstraction; (2) ascription of feature constraints; (3) generation of instantiated models in working memory; and (4) the feelings of understanding. Usually, an explanation begins at the stage of generic abstraction, in which two kinds of constraints on modeling a phenomenon or conceptual construct (e.g., Boyle's law) are temporarily fixed: One is a set of feature constraints that characterize the phenomenon or construct; another is a set of variable (and/or a set of constants) that describe the initial and boundary conditions of the explanandum. In contrast to the mental modeling model of generating a new conceptual structure (see Nersessian 2002, p.152), the following step is not to construct an initial model for target, but to search for a suitable relation of ascription under some representational forms of knowledge stored in long-term memory – It should be noted that this process is often involved in an elimination of the one to many ascription in light of specific cognitive goals and background knowledge. At the third stage of explanation by model-based reasoning, an instantiated model is generated by information stored in long-term memory and by the constraints that describe the initial and boundary conditions of the explanandum. Finally, the agent who undertakes the explanation undergoes the experience of understanding the explanandum through an internal process of mapping.

Therefore, explanation is a semantic process of understanding based on mental models, in which tacit or implicit constraints are often used to construct instantiated models. This is a fundamental reason why it is impossible in principle to construct a logical structure linked the explanandum with the explanans. In other words, instantiated models are not the explanans in Hempel's models of scientific explanation even though such kinds of explicit knowledge contained in the explanans are necessary constraints that are used to construct instantiated models. Thus, information stored in long-term memory that covers the explanandum cannot produce an explanation if it does not support the construction of an instantiated model.

References

Brewer, W. F. (1999). Scientific theories and naive theories as forms of mental representation: Psychologism revived. *Science and Education*, *8*, 489-505.

Brewer, W. F., Chinn, C. A. & Samarapungavan, A. (1998). Explanation in scientists and children. *Mind and Machines*, *8*, 119-136.

Gentner, D., & Stevens, A. L. (Eds.)(1983). *Mental Models*. Hillsdale, NJ: Erlbaum.

Hempel, C. G. (1966). *Philosophy of Natural Science*, Englewood Cliffs, NJ: Prentice-Hall.

Nersessian, N. J. (2002). The cognitive basis of model-based reasoning in science. In P. Carruthers, S. Stich, & M. Siegal (Eds.), *The Cognitive Basis of Science*. Cambridge, UK: Cambridge University Press.

Salmon, W. C. (1998). *Causality and Explanation*. Oxford: Oxford University Press.