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Model-Based Reasoning in Normal Science

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A view of scientific cognition as *model-based reasoning* (MBR) has increasingly occupied the recent literature, and the accounts of mental modeling have provided an elementary understanding of the cognitive basis of scientific reasoning. As a reaction direct to the received view, these kinds of semantic approaches to scientific cognition focus on the problems of the generation and change of conceptual structures in the contexts of discovery and development. This paper will characterize scientific practices of normal science within the framework of scientific cognition as MBR and show that scientific practices in normal science share the same kinds of underlying cognitive processes with those in the contexts of discovery and development.

Nersessian (2002a, 2002b) uses a cognitive-historical approach to the case of Maxwell's electromagnetic theory and points out that MBR is a central characteristic of scientific reasoning during scientific revolution. According to our analysis of this paper, it is informed by the historical case that MBR provides undoubtedly the possibility of genuine scientific creations but is not characteristic only of scientific reasoning in the processes of revolutionary changes. The case of Maxwell's theory does show that MBR is foundational cognitive processes of scientific practices of reasoning in the stage of normal science.

There are three important aspects in our analysis of the concept of paradigm as constraints of modeling: a disciplinary matrix as explicit constraints; exemplars as implicit/tacit constraints; and puzzle-solving as MBR according to one fixed set of constraints. Thus, it is possible to account for scientific practices of normal science in light of the key characteristics of the use of mental models in reasoning (Johnson-Laird, 2001; Byrne & Johnson-Laird, 1989, 1990; Johnson-Laird & Byrne, 1991). First, a mental model captures what is common to all the possibilities even though it represents only one possibility satisfying constraints of modeling. In the practices of normal science, the central function of exemplars is to represent the modeling constraints involved in a paradigm in a cognitively manageable way, such that scientists develop other models through a processes of inference by similarities. Second, mental models represent what is true relative to modeling constraints, and thus may lead to systematic errors. The similar situations would happen in reasoning practices of normal science – for example, the historical cases of the particle theory when it was used to explain phenomena of light such as reflection, refraction, and Newton ring. Of course, it should be noted that, due to the function of generic abstraction, new constraints can emerge in the processes of model-based reasoning, even those that suggest us to reject the old entrenched constraints,

as shown in Nersessian's analysis (Nersessian, 2002b). Third, procedures of model-based reasoning in ordinary inferential tasks rely entirely on alternative models to refute invalid inferences. The subject would confirm the inference from the initial models in the case that there are no incompatible alternative models or that he/she could not find out alternative models. This may be the reason why a genuine valid refutation against an existent hypothesis in reasoning practices of normal science is to put forward incompatible alternative hypotheses; oppositely, the fact that there are no alternative hypotheses which could be developed is a strong argument for an existent hypothesis. Finally, the greater the number of models that a task needs, the poorer performance is. In fact, the number of mental models involved in a task is inversely proportional to the amount of modeling constraints. Kuhn expounds how the 'would-be' researchers acquire capacities to do research work in a specific discipline through the inferential training similar to that of exemplar-exercises in textbooks. The cognitive processes similar to learning based on exercises in textbooks is required for the training of researchers even though the processes of two kinds are fundamentally different in a sense that a question involved in exercises has usually a single definite resolution (model) but researchers in actually scientific practices have to find out a variety of unknown constraints of modeling.

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