Preface

by Lorenzo Magnani[a] and Nancy J. Nersessian[b]

These articles in this special issue of the journal *Mind and Society* focus on "Commonsense and scientific reasoning" and are a selection of the papers that were presented at the International Conference *Model-Based Reasoning: Scientific Discovery, Technological Innovation, Values* (MBR'01), held at the Collegio Ghislieri, University of Pavia, Pavia, Italy, in May 2001.

Over seventy papers exploring how scientific thinking uses models in exploratory reasoning to produce creative changes in theories and concepts were presented at the conference. Some addressed the problem of model-based reasoning in ethics, especially pertaining to science and technology, or stressed some aspects of model-based reasoning in technological innovation.

The study of diagnostic, visual, spatial, analogical, and temporal reasoning has demonstrated that there are many ways of performing intelligent and creative reasoning that cannot be described with the help only of traditional notions of reasoning such as provided by classical logic. Traditional accounts of scientific reasoning have restricted the notion of reasoning primarily to deductive and inductive arguments. Understanding the contribution of modeling practices to discovery and conceptual change in science requires expanding scientific reasoning to include complex forms of creative reasoning that are not always successful and can lead to incorrect solutions. The study of these heuristic ways of reasoning is situated at the crossroads of philosophy, artificial intelligence, cognitive psychology, and logic; that is, at the heart of cognitive science.

It has long been a fundamental premise of cognitive studies of science that the heuristics employed in scientific reasoning are extensions of those employed in ordinary problem solving and that study of either illuminates the other. Think, for example, of one how usually solves the problem of how to get an awkward piece of furniture through a door. The usual procedure is not to run through a series of logical inferences on premised describing the situation. Rather, the reasoner usually men-

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tally simulates turning over an object roughly approximating the geometrical configuration of the piece, e.g, a chair. This is an elementary form of what we are calling model-based reasoning.

Several key ingredients common to the various forms of model-based reasoning have been considered. The term "model" comprises both internal and external representations. The models are intended as interpretations of target physical systems, processes, phenomena, or situations. The models are retrieved or constructed on the basis of potentially satisfying salient constraints of the target domain. Moreover, in the modeling process, various forms of abstraction are utilized. Evaluation and adaptation take place in light of structural, causal, and/or functional constraints. Model simulation can be used to produce new states and enable evaluation of behaviors and other factors.

In traditional philosophical accounts what we call model-based reasoning practices are considered ancillary, inessential aids to thinking. At most they have constituted fringe topics in the literature in philosophy of science. Embracing these modeling practices as the reasoning through which problem solutions are generated requires expanding philosophical notions of scientific reasoning to encompass forms of creative reasoning, most of which cannot be reduced to an algorithm in application, are not always productive of solutions, and can lead to incorrect solutions. To do this requires challenging one of the most sacrosanct notions in philosophy: "reasoning". In the traditional view, the identification of reasoning with argument, and thus with logic, is deeply ingrained. So, before we can develop a notion of "model-based reasoning" in science, we need first to address the question "What is reasoning?" and, specifically, "What is scientific reasoning?"

In standard philosophical accounts reasoning is applying deductive or inductive algorithms to sets of propositions. The understanding of deductive reasoning provided by classical logic stands as the model. Here the essential notion is soundness: true premises plus good reasoning yields true conclusions. On extending the traditional notion of reasoning to what goes on in the domain of scientific "discovery" a problem arises immediately. Good reasoning, with *T* premises can lead to incorrect solutions or to no solution at all. For example, Newton's path to the concept of universal gravitational force was largely through *analogy*. Analogical argument is a notoriously weak form of argument and one could hold that concerns about it have been borne out in this case. According to the general theory of relativity, that conclusion is wrong. There is no gravitational force, falling bodies are just following their natural trajectory in a curved space-time. But, of course, we know this could prove to be wrong as well. The problem of unsoundness has been a factor in the contention of philosophers of various persuasions that there is no "logic of discovery".

Some nontraditional philosophical accounts have allowed for the possibility of *abductive* inference. Analyzing modeling practices provides a way of specifying the nature of some abductive reasoning processes. Many kinds of abductions involving analogies, diagrams, thought experimenting, visual imagery, etc. in scientific discovery processes, can be called *model-based*. The concept of *manipulative abduction* was introduced by Magnani (2002) to capture the role of action and of external representations in many interesting situations: action provides otherwise unavailable information that enables the agent to solve problems by starting and performing a suitable abductive process of generation or selection of hypotheses.

Research in the cognitive sciences, especially cognitive psychology, artificial intelligence, and computational philosophy, have established that heuristic procedures are reasoned. Nersessian (1992, 1999) has demonstrated how the practices of analogical modeling, visual modeling, and thought experimenting have played generative roles in concept formation in science and she has developed a "cognitive-historical" account of how these model-based reasoning function in conceptual innovation and change and in learning.

The various contributions to this special issue are written by interdisciplinary researchers who are active in the area of creative reasoning in science. They aim to increase knowledge about the relationship between scientific and commonsense reasoning by illustrating some of the most recent results and achievements of the model-based reasoning research. The papers focus on such issues as the characterization of scientific reasoning (in natural and human sciences) and everyday reasoning: the role models in science and mental models in scientists and nonscientists (W.F. Brewer), the various developmental issues in model-based reasoning during childhood (P. Miller), the character and the problems of the so-called "coupled clustering", a novel computational framework for detecting corresponding themes in unstructured data (Z. Marx and I. Dagan), the analysis of the way in which an observer interprets events involving objects in terms of action carried out by agents in order to reach goals (E. Zibetti, F.S. Beltran, V. Quera, and C. Tijus), and the function of rules and model-based reasoning in moral judgments (A. Goldman).

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Several papers deriving from the presentations given at the Conference have already been published in the book L. Magnani and N.J. Nersessian, eds., *Model-Based Reasoning: Science, Technology, Values*, Kluwer Academic/Plenum Publishers, New York, 2002. The more logically and computationally oriented papers deriving from the presentations given at the Conference have been published in the book *Logical and Computational Aspects of Model-Based Reasoning*, edited by L. Magnani, N.J. Nersessian, and C. Pizzi, which appeared in the Applied Logic Series, directed by. D.M. Gabbay and Jon Barwise, of Kluwer Academic, Dordrecht, 2002. The remaining selected papers will be published in four more Special Issues of Journals: in *Foundations of Science*, Abductive Reasoning in Science; in *Foundations of Science*, Model-Based Reasoning: Visual, Analogical, Simulative; in *Mind and Society*: Scientific Discovery: Model-Based Reasoning, all edited by L. Magnani and N.J. Nersessian; in *Philosophica*, Diagrams and the Anthropology of Space, edited by K. Knoespel.

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