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Model-based Reasoning in Science and Technology: Theoretical and Cognitive Issues

LORENZO MAGNANI (Ed.)
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Models are simplified representations or descriptions of systems, which aim to capture characteristics that are considered fruitful for further study of those systems. Modelling entails the activity of demonstrating or revealing by capturing properties that are considered to be conducive to the understanding of those using the models in question. Given the crucial role that models play in the natural, social, and applied sciences, studying the relationship between modelling and knowledge is of great importance.

The book, *Model-based Reasoning in Science and Technology: Theoretical and Cognitive Issues*, gathers papers presented at a conference with the same title that took place in Sestri Levante, Italy, in 2012. All authors involved engage with 'model-based reasoning' (MBR): the various ways in which models and modelling are intertwined with scientific practice and technological development. Lorenzo Magnani argues in the preface that this approach is needed, since more established ideas about reasoning cannot always properly explain how discovery and conceptual change take place in science. As a result, it is necessary to expand 'the concept of reasoning to include complex forms of creativity that are not always successful and can lead to incorrect solutions' (vi). MBR is presented as a necessary line of reasoning that can augment studies of science and technology in such a way that the aforementioned shortcomings are overcome. This requires a few basic premises: models involve both internal and external representations that entail interpretations of target systems, and 'are retrieved or constructed on the basis of potentially satisfying salient constraints of the target domain'; the observation that 'in the modeling process, various forms of abstraction are used. Evaluation and adaptation take place in the light of structural, causal, and/or functional constraints'; and finally that '[m]odel simulation can be used to produce new states and enable evaluation of behaviors and other factors' (vi).

The book (and MBR more generally) adopts an interdisciplinary approach that combines insights from philosophy, artificial intelligence, cognitive science, logic, and historical studies of science, engineering, and architecture. The large variety of approaches and topics echoes the geographical and disciplinary variety of the group of authors involved. The 34 chapters in the book are presented in three sections: 'Models, Mental Models, Representations', 'Abduction, Problem Solving and Practical Reasoning', and 'Historical, Epistemological, and Technological Issues'. Given the size of the book, the three sections can still feel somewhat overwhelming. Numbering the chapters would have come in handy. Due to the richness and multi-layered nature of the book as a whole, I cannot hope to do justice to the wealth of insights contained in this vast volume. However, I will point the reader towards the main currents that flow through the book.

Models and fictionalism. Although models have an irreducible perspectival character, as Manuel Liz claims, none of the authors in this book commits to a fictionalist explanation of MBR. Given the fact that several philosophers of science commit to fictionalism (e.g. Bas van Fraassen), this is certainly a worthwhile line of thought, which is explored substantially. The book provides ample opportunity to reflect on the feasibility of fictionalism vis-à-vis MBR and modelling more generally. Several authors (John Woods, Demetris Portides, and Michel Ghins) deal with fictionalism by refuting it in various ways. Portides argues that fictionalism falls short in explaining scientific discovery:

> Successful representational models should be considered true enough not just because their predictions approximate the values of experimental measurements or because they bear similarity relations with what they represent, but also because they produce new knowledge about their target . . . this is the result of the

> interplay between the model and the target of the model, and it is a necessary characteristic for a model to be successful in science. (76)

Models as instruments. Barbara Tversky shows how models are part of the instruments of thought that yield understanding. According to Chris Sinha, even our basic conception of time can be explained by MBR. Christian Tamas argues that MBR can be used to explain analogies between holy scripture and the world. Mikkel Willum Johansen claims that MBR plays a profound role in mathematics in the form of diagrams, since the latter are material anchors for conceptual mappings. Framing the use of diagrams as such explains the functional role of conceptual mappings in the production of mathematical knowledge (89). Paul Thagard and A. David Nussbaum explain how modelling and computer simulation yield an understanding of various phenomena, such as fear-driven and motivated inference. Paolo Pecere, Alfredo Pereira Jr., and Fábio Augusto Furlan explain how MBR can be applied to research in neurology.

Models and abduction. Abduction, better known as inference to the best explanation, is dealt with by Woosuk Park, Priyedarshi Jetli, and Jun-Young Oh and Yoo Shin Kim, who explain that abduction can be observed in animals, in Plato's *Meno*, and in the discovery of the moons of Jupiter by Galileo Galilei, respectively. As such, these chapters display the 'archaeological and interdisciplinary effort' that is mandatory in understanding abduction, according to Magnani (173ff.). At this point in the book, considerations of MBR in practice play a more prominent role. Emiliano Ippoliti discusses ampliation, or the introduction of 'properties, relations, and entities that are not contained in the data at the beginning of the inferential process' (248). Ampliation cannot be dealt with logically due to the underdetermination of hypotheses by data: a multiplicity or even infinity of hypotheses can be generated by the same data. The generation of hypotheses therefore demands not so much the formulation of strict rules or recipes, but rather a 'heuristic viewpoint' (247), which explains how ampliation takes place in practice. Similarly, H. G. Callaway argues that 'in selecting among untested hypotheses, we have to do with a highly contextual type of judgement, a kind of art or wisdom arising from the expert's familiarity with the subject-matter' (279). Creativity and expert judgement play a profound role in scientific practice and are coupled with hypothesis generation in Antonino Drago's contribution. Cognition is situated and distributed, as Pedro Atã and João Queiroz show, something which according to Sara Dellantonio and Luigi Pastore also reverberates in the cultural, individual, and situational differences in moral judgement, cross-cultural and trans-individual similarities notwithstanding. According to Jeffrey White, MBR is profoundly creative since a

> model is a representation of salient aspects of a system that, when rendered together, articulate an essential function in a more efficient way than the original, a replica or a duplicate. So, models are used for reasons other than for the creation of one of these other things. (363)

Models in action. Models have important heuristic functions in their areas of application, as illustrated primarily in the third part of the book. Case studies often revolve around the role of MBR in physics, though biology, artificial intelligence, and architecture are also discussed in the book. Ryan D. Tweney argues that cognitive science and MBR can be used to explain the role of mathematics in physics. Models are crucial catalysts of new ideas in science, as Tjerk Gauderis shows, since models 'invite scientists by their functional structure to actively explore old ideas in order to adapt them for their own purposes' (460). The third part of the book also ventures onto more methodological terrain, for example, by pointing out the advantages of agent-based modelling, which according to Ruggero Rangoni allows for 'greater realism in the assumption compared with mathematical models; strict deduction in the inferential process from those assumptions, eliminating the vagueness of informal thought experiments' (471). Integrating scientific experimentation into engineering activities is proposed as a promising way to overcome technical problems and open up new vistas of thought in technical innovation, such as robotics. The contexts in which model output is considered and how those contexts mark an experiment as generative or demonstrative form the focus of Tommaso Bertolotti's chapter. As Margarita Vázquez and Manuel Liz argue, expert judgement can be an important part of model construction. In fact, experts play a crucial role in the attribution of value to model output: as designers 'seek out models to assist with design issues, they look not only for instruction but also for validation' (623).

Concluding remarks. The topics presented above hint towards lines of inquiry encountered in the humanities and social sciences that are involved with the study of models, for example, the role of expert judgement in science, how models establish trust in science and engineering, and how scientists and engineers relate to the models they use in their work. Studying the aforementioned issues from the perspective of MBR provided me with a refreshing experience. I look forward to my next encounter with this vibrant field of scholars.

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Jung and the Question of Science

Raya A. Jones (Ed.)

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More than a century after the publication of the second part of *Wandlungen und Symbole der Libido* (1912), in which the influential Swiss psychiatrist C. G. Jung distanced himself from his teacher Freud and founded his own depth psychological school under the name of 'analytical psychology', it is about time we started a serious and sufficiently critical debate about the academic value of Jung's methods