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Model-based science: diverse perspectives, little cross-disciplinary dialogue

Review of Lorenzo Magnani and Tommaso Bertolotti (Editors):
Springer handbook of model-based science.
Dordrecht: Springer, 2017, 1179pp, US$399.99HB

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Modeling is integral to theoretical and experimental practice across the sciences. In virtually all disciplines, models and simulations help advance scientific understanding in many different ways, such as in illustrating and testing theoretical implications, in generating and analyzing experimental data, in evaluating novel methodological approaches and tools, and in providing analogues for the investigation of real-world phenomena. While model-based research is not new, it was only in the past few decades that modeling became an object of investigation in its own right: In addition to *using* models to understand the world, researchers in the natural and social sciences as well as in the humanities have recently begun paying closer attention to the very instruments and processes that make up model-based scientific research and model-based reasoning more generally. The *Springer Handbook of Model-Based Science*, edited by Lorenzo Magnani and Tommaso Bertolotti, presents a broad picture of this rich and fast-growing literature. At close to 1200 pages, the volume is sure to have something relevant for most interested readers. The editors also did well to create such a diverse collection, selecting chapters that can act as entry points for readers new to particular topics and that can also challenge the initiated and push the literature forward.

The *Springer Handbook of Model-Based Science* contains 53 chapters organized in eleven parts that I describe here as falling into four broad categories. Part A:

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“Theoretical Issues in Models,” edited by Demetris Portides, is the general philosophy of science section of the book, and it provides an introduction to traditional philosophical issues concerning modeling in science, including debates about representation, about the ontology of models, and about how modeling relates to theorizing, explanation, and simulation. Part B: “Theoretical and Cognitive Issues on Abduction and Scientific Inference,” edited by Woosuk Park, and Part C: “The Logic of Hypothetical Reasoning, Abduction and Models,” edited by Atocha Aliseda, form a cohesive unit on logic, induction, abduction, and hypothetical reasoning. Part D: “Model-Based Reasoning in Science and the History of Science,” edited by Nora Alejandrina Schwartz, is the history and philosophy of science section of the volume, with chapters emphasizing historical and cognitive aspects, especially Chapters 16–18, as well as more conceptual and formal aspects, as in Chapters 19–21. The chapters in these three categories occupy the first half of the book.

The second half of the *Handbook*, Parts E through I, can be seen as a fourth category of chapters concerned with philosophical and theoretical issues within particular sciences and analyzed through discipline-specific case studies. Part E: “Models in Mathematics,” edited by Albrecht Heeffer, examines geometric, diagrammatic, and formal reasoning through theoretical, historical, and applied pedagogical lenses. Part F: “Model-Based Reasoning in Cognitive Science,” edited by Athanassios Raftopoulos, touches on topics such as visual perception, the relation between cognition and action, and mechanistic and complex systems approaches to studying cognition. Part G: “Modeling and Computational Issues,” edited by Francesco Amigoni and Viola Schiaffonati, starts out with chapters on computational models of cognition and of scientific discovery, and it ends with more methodologically oriented discussions about the epistemology of simulation and experimentation in robotics. Chapters in Part H: “Models in Physics, Chemistry and Life Sciences,” edited by Mauro Dorato and Matteo Morganti, show how instances of model-based research in particular fields such as physics, chemistry, biology, and geosciences provide both general and discipline-specific lessons for understanding scientific modeling. And Part I: “Models in Engineering, Architecture, and Economical and Human Sciences,” edited by Cameron Shelley, concludes the *Handbook* with chapters on modeling and model-based reasoning in fields such as archeology, design, engineering, education, law, and economics.

The *Handbook* has many virtues. The one I want to highlight here is the remarkable diversity it exhibits on multiple levels. First of all, almost half of the 53 chapters in the volume were written by a female author or co-author. This close balance is worth celebrating as a step toward mitigating the wider gender inequalities still pervasive in academia (see, e.g., Winslow and Davis 2016). Also notable is the international makeup of the *Handbook*: The authors of the 53 chapters are affiliated with institutions in almost twenty different countries, including universities outside of North America and Europe, making this a representative sample of a truly international

literature. And last but not least is the *Handbook*'s striking disciplinary diversity. Chapter authors and area editors are affiliated with departments and programs in philosophy, logic, psychology, education, economics, law, mathematics, computer science, engineering, robotics, and more. By bringing together contributions from scholars in so many different fields, the *Handbook* makes it possible for readers already positioned in one corner of the literature to broaden their perspective and become acquainted with ideas and approaches from other disciplines.

And while disciplinary diversity is one of the key strengths of the *Handbook*, it also points in the direction of the *Handbook*'s weaknesses. When describing the eleven parts in which the *Handbook* is organized I suggested that they fall into four broad categories: general philosophy of science; logic and formal reasoning; historico-cognitive approaches; and philosophy of particular sciences and case studies. This categorization gives a flavor of the *Handbook*'s overall composition, and, importantly for the present point, it also captures the *Handbook*'s lack of cross-disciplinary dialogue. By and large, each of the four categories I identified constitutes its own self-contained conversation, with little to no acknowledgment of ideas and approaches in the other categories. The clearest example of this pattern is found in the chapters belonging to the second category, on logic and formal reasoning, located in Parts B and C. For instance, the opening chapter of Part B, Chapter 6, "Reorienting the Logic of Abduction" by John Woods, provides an interesting introduction to epistemological issues relating to abductive reasoning, but it does not in any way indicate how this topic is relevant for making sense of model-based science: Only in the context of other chapters does it become clear that, according to some views, scientific modeling is understood as a variety of abductive reasoning. Many of the other chapters in Parts B and C similarly appear to relate to model-based science only indirectly, offering accounts of reasoning patterns and leaving it to the reader to infer that those patterns are hypothesized to occur in scientific modeling (see, e.g., Chapter 12, "Modeling Hypothetical Reasoning by Formal Logics" by Tjerk Gauderis).

But it is not only chapters in Parts B and C that lack a clear connection to larger debates outside a particular discipline. Chapters in Part A similarly pay very little attention to issues raised in historical, cognitive, and discipline-specific approaches. Thinking about this pattern, and about exceptions to it, raises further questions about the *Handbook*'s overall organization. On the one hand, there are cases of chapters in close thematic proximity that should be in dialogue but are not—see, e.g., Chapter 22, "Diagrammatic Reasoning in Mathematics" by Valeria Giardino, in Part E, and Chapter 27, "Diagrammatic Reasoning" by William Bechtel, in Part F. On the other hand, there are also cases in which chapters relate so well with contributions in other parts that they even seem to be misplaced. For example, Chapter 19, "Hypothetical Models in Social Science" by Alessandra Basso, Chiara Lisciandra, and Caterina Marchionni, in Part D, touches on so many foundational issues that it could instead

have been placed in Part A along with general philosophy of science chapters, or, due to its disciplinary focus, in Part I along with chapters on the social sciences. Similarly, Chapter 43, “Models and Mechanisms in Cognitive Science” by Massimo Marraffa and Alfredo Paternoster, in Part H, could easily fit in Part F with other chapters on modeling in cognitive science, particularly alongside Chapter 27. Cases such as these make the eleven parts of the *Handbook* sometimes feel like eleven different journal issues on more or less related topics rather than contributions to one and the same conversation.

To be clear, these weaknesses do not detract from the merits of the *Handbook*. In fact, fragmentation along certain disciplinary boundaries is not an artifact of the *Handbook* but a feature of the literature itself, such that there is little the editors could have done to promote more cross-disciplinary dialogue. There is still a wide gap separating traditional conceptual perspectives from empirically informed ones, and separating conversations about model-based science from conversations about model-based reasoning. Notable recent accounts that bring philosophy to bear upon cognitive approaches or that bring cognitive findings to bear upon philosophical approaches include, respectively, Nersessian (2008) and Potochnik (2017), but these are exceptions that prove the rule. The literature on modeling largely remains a series of parallel disciplinary conversations with very little truly cross-disciplinary interplay, and this is a fact that the *Handbook* captures well. Perhaps bringing together these diverse and separate perspectives in a single volume is a first step toward making interdisciplinary insight more feasible, and certainly for this reason the *Handbook* is a very welcome addition to the literature.

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