The Functions of Models
How to do Science with Models. A Philosophical Primer
By Axel Gelfert

Axel Gelfert's recent book *How to do Science with Models. A Philosophical Primer* constitutes a short but important contribution to a growing literature devoted to explore a number of philosophical issues raised by the ubiquity of models within the sciences and also by the great variety of existing models and modeling practices as well as their indispensability to the scientific enterprise. As Gelfert remarks in the introduction, philosophical inquiry on models and modeling has been vigorously pursued in the last few decades, but with a limited scope. Indeed, for Gelfert, most scholars working on models have either focused on (1) developing a comprehensive theory of models that can reveal their nature and account for their representational capacities or (2) offering in-depth analyzes of particular models that illuminate the specific mechanisms through which each individual model is created and functions. To circumvent the limitations of each approach, Gelfert (p. iv) suggests the adoption of a key methodological assumption, which is that 'careful attention to scientific modeling as a practice may itself be a source of insight about what gives model-based science its cohesion and makes it successful.'

On the basis of this assumption, Gelfert presents a thorough and compelling case throughout the book for this thesis: rather than having an underlying nature, what unifies models and what explains their success in science is the fact that they are typically constructed and used as *tools* to perform a variety of different functions. In particular, Gelfert argues that, though scientific modeling is often done to represent some phenomenon, the construction and deployment of models also serves other functions beyond scientific representation. In order to argue for this thesis, Gelfert proceeds as follows. In Chapter 1, Gelfert presents and rehearses the traditional ontological debate about the nature of models. One of the virtues of this chapter is that Gelfert adroitly shows through a historical discussion of different positions (which include the analogy view of Mary Hesse, the semantic view that Patrick Suppes and Bas van Fraassen embrace and various versions of the fictionalist view defended by Nancy Cartwright, Mauricio Suárez and Roman Frigg) that there are serious doubts concerning whether any of these of these positions can account for the huge diversity of existing models in a way that unifies them, thus providing support for an pragmatic position relying on the thesis that (p. 20) '*what models are* is crucially determined by their being the result of a deliberate process of model construction.' If this is the case, then there is no intrinsic nature that models have, but what they are turns out to depend on the particular function(s) they have.

This characterization of models as functional entities (which Gelfert adopts in chapter 2) is then applied to address certain questions that arise with respect to the use of models in scientific representation. As Gelfert shows, philosophers of science have traditionally toiled to provide an account of how models can represent and have put forth different proposals. In particular, Gelfert presents and discusses in detail the DDI account developed by Gabriele Contessa and the inferential account articulated by Suárez after examining briefly the issue of whether there is anything distinctive about scientific representation that sets apart from other forms of representation (e.g., artistic). One of the great accomplishments of Gelfert in this chapter consists in showing how viewing models as functional entities allows us to provide an account of models that subsumes the best ideas of Contessa and Suárez: models are able to represent in certain cases because they can perform functions such as denotation, demonstration and interpretation vis-à-vis their targets (which are the three core elements of Contessa's DDI account) or because they can be used to undertake other specific functions, such as drawing inferences from their targets (which is the core of Suárez's account). Finally, Gelfert shows at the end of the chapter how the functional view of models can help us make sense of the thesis that, even if models are strictly speaking false, they can nevertheless make key contributions to scientific inquiry not only through their representational uses but also through other uses.

The last three chapters contain, in my view, Gelfert's most important insights and contributions. In chapter 3, Gelfert offers a thorough analysis of several case studies of models in various disciplines to try to identify recurring patterns in model building. As he tries to chart a middle path between the abovementioned options (1) and (2), Gelfert shows through a detailed study of several examples (in particular, the BCS model, the Hubbard model and the Lotka-Volterra model) that these models are always developed with certain specific purposes in mind: prediction in certain cases, explanation in others, testing in further others. Thus, one of the key recurring patterns that Gelfert identifies in his analysis is that model construction is sensitive not to the specific disciplines (e.g., physics, biology, etc.) where it is practiced, but rather to the specific functions that the model developers intend their creations to perform. The identification of this pattern enables Gelfert to explain why Richard Levins' contention that model building involves trade-offs between many different desiderata (e.g., generality, accuracy, complexity, etc.) is correct. Indeed, just as a good wrench is built for a specific function and is consequently ill-suited to perform other functions (e.g., cutting wood), so a model, if it is developed and successfully used to perform a specific function (e.g., predicting changes in rainfall in some region), is often ill-suited to perform other functions (e.g., representing the whole target system).

The last two chapters offer further support to Gelfert's central thesis by showing that different models have different functions. In chapter 4, Gelfert defends the view that some models have an exploratory function. In this respect, they are similar to certain experiments which aim 'not just at bringing about a well-defined observable change in the world, but also serve as a testing ground for new, yet to be stabilized concepts' (p. 76). After introducing this claim and providing some general support for it based on the views of computer scientists such as John Holland and physicists such as Nigel Gogenfeld, Gelfert offers a taxonomy of different ways in which models functions as exploratory tools. This taxonomy includes the use of models (*a*) as starting points, (*b*) as key parts in proof-of-principle demonstrations, (*c*) as ways to develop potential explanations and (*d*) as tools to explore the suitability of the target. Finally, in chapter 5, Gelfert argues for the view that certain models do not only function as mediators (a thesis previously defended by Margaret Morrison and Mary Morgan), but also as contributors and enablers of scientific knowledge. This is the most interesting chapter of the book and contains the richest philosophical insights. In particular, Gelfert shows how models that are built using 'formalism-driven' construction not only integrate various theoretical and experimental elements, but also often contribute new elements. For instance, in the case of the Hubbard model, Gelfert shows how the model can provide new contributions at various levels. At a basic level, Gelfert argues that 'new quantities and parameters may be generated by combining different elements of the model' (p. 110). At a deeper level, the model can contribute rigorous results, which are a class of 'exact mathematical relationships between certain mathematical variables, or certain structural components, of the mathematical model' (p. 111). In addition, Gelfert shows how models can function as enablers of scientific knowledge insofar as they 'enable different kinds of *user-model-target* relations' (p. 120). Drawing on the work of Don Ihde, Gelfert distinguishes embodiment relations from hermeneutic relations and uses this framework to show how models function as enablers of knowledge in different ways. More specifically, Gelfert argues that certain models are enablers of scientific knowledge insofar as they function in ways similar to glasses or telescopes (which are treated as extensions of one's body), while other models are enablers as they function as in ways similar to written texts or maps which provide information about the world only through a certain interpretation. Furthermore, Gelfert argues by considering in detail two examples (namely, the Phillips machine and interactive computer graphics used in contemporary protein modeling) that, in certain contexts and for certain purposes, model users emphasize embodiment relations whereas, in other contexts and for other purposes, they emphasize hermeneutic relations. In virtue of this, models may, for Gelfert, 'function as mediators between different user-model-target relations' (p. 124). In my view, this claim is the most original insight of the book.

The only minor reservation that I have about Gelfert's book is that the taxonomy that he offers in chapter 4 is incomplete. In particular, Gelfert forgets to mention the use of certain highly abstract models (which are a kind of thought experiments) for exploratory purposes, which had been identified and discussed by Ernst Mach. But this is only a small shortcoming and, other than this, the book is an outstanding and original piece of scholarship.