

INTRODUCTION

In this text I shall offer a model-theoretic realist interpretation of the processes and products of science built on recent work in the philosophy of science dedicated to analysing the natural sciences in terms of conceptual (mathematical) models of theories and the various semantic relations between such models, theories, and (aspects of) reality. Although analyses of theory-reality and model-reality links have long been a part of philosophy of science, I shall concentrate on the more recent developments concerning these issues in a *model-theoretic* context. Such analyses touch on core questions of the philosophy of science, such as questions regarding the nature of scientific theories, the usual realist inspired questions about the possibility and character of relations between scientific theories and reality, the notion of scientific truth, and, in general, on the nature of scientific progress.

This book has two themes. In one sense I mean it as an introductory text on formal semantic analyses (especially those making use of model theory) in philosophy of science over the past 70 to 80 years. On the other hand I mean this book as an introductory exposition of my account of model-theoretic realism. I join these themes by setting out and explaining a model-theoretic realist account of science against the background of other developments in formal semantics. Mary Morgan and Margaret Morrison (1999) in their book entitled *Models as mediators* make the point (*ibid.*, pp.12,13) that philosophy of science texts in general offers very little information on how models are built. I think there is also very little on exactly what are taken as “models” by different philosophers, and on what the goals and also the consequences of introducing “models” in philosophy of science really are.

A model-theoretic realism offers, via analyses of the structure of scientific theories and the processes of science, a scientific realism that needs, apart from the ontological assumption that the world exists independently of us, very little else from metaphysics. This particular kind of realism is simple although sophisticated, and, as such, implies that although reality is acknowledged to exist “outside” of human practice, this neither means that reality is unknowable nor, at the other extreme of the scale, that science simply mirrors it. By analysing the structure of scientific theories model-theoretically (Chapter 2), it will be shown (Chapter 5) that a model-theoretic approach to science and its processes and products offers the best kind of scientific realism — i.e. a scientific realism with as little metaphysical content as possible.

First a few words on the notion of “science” as it will be used in this text. In principle, my interpretation of science is applicable to all sciences (natural, behavioural, human, social, economic, and so on). I shall in this book however put the emphasis almost exclusively on the natural sciences, and in particular on physics, for the following reason: all of the three main aspects of my model (or interpretation) of science (namely empirical models, interpretative, conceptual models, and theories) are — mostly — more simple and more clearly delineated in the case of the natural sciences (and in physics in particular) than in the other sciences. However, in Section 1.4 I briefly discuss the use of the notion of “model” in economics, and in Section 2.6 I briefly explore the relations between theories and models in methodological studies of

economics to illustrate the applicability of a model-theoretic approach outside the natural sciences.

The use of the notion of models is nothing new in either philosophy of science or the (empirical) sciences themselves. Writers such as Achinstein (1968), Hesse (1963), and, more recently, Redhead (1980) have paid much attention to the heuristic uses of models in the development of scientific theories. In his article, entitled *A comparison of the meaning and uses of models in mathematics and the empirical sciences*, Patrick Suppes (1960) reviews the various uses of the notion in mathematical statistics, psychology, economics, and physics. Nancy Cartwright (1989, 1995a, 1995b) also often makes use of the analogies between the ways in which models are used in economics and theoretical physics to illustrate her views of the nature of scientific theories. In Section 1.1 I shall give a brief overview of some of the different interpretations and uses of the notion of “model” in philosophy of science.

In current philosophy of science, many interesting questions centre around the ways in which writers distinguish between and assign roles to theories and the mathematical structures that interpret them and in which they are true, i.e. between scientific theories as linguistic systems and their non-linguistic models. In this context I shall set out my own model-theoretic account of the processes and products of science.

Philosophy of science literature offers us mainly two approaches to the structure of the products of science analysed in terms of linguistic and non-linguistic systems, the “statement” or syntactic approach, and the “non-statement” approach. The statement approach is characteristic of philosophers and logicians like Carnap, Hempel, and Nagel. The advocates of this approach use the tools of mathematical logic to depict theories as axiomatic systems in some well-defined language, and study the syntax and semantics of theories via the proof and model theories of language. The advocates of the non-statement view of science’s products generally emphasise the tools of algebra and set theory. This approach originated with Poincaré’s work in geometry and mechanics and has started developing through semantic analyses of non-statement reconstructions of certain scientific theories done by Von Neumann (1955), Adams (1959) and Suppes (see McKinsey, Sugar & Suppes (1953), Suppes (1959)), and also Montague (1962).

Defenders of the statement or “received”¹ account of scientific theories depict the rational reconstruction of the language of science as a syntactic system with an axiomatised deductive theory formulated within that system. Its defenders usually characterise theories in terms of two parts. First they identify an abstract formal calculus (a symbolic language) in which the primitive symbols (which in this case are terms that do not have obvious relations with “observation” terms, i.e. so-called “theoretical” terms like “electron”, “particle”, “mass”, and so on) of the theory are set out. The second part of the structure of a scientific theory they depict as a set of rules (called “correspondence rules” by Carnap and “bridge principles” by Hempel) that assigns empirical (observational) content to the logical calculus by providing “co-ordinating definitions” or “empirical interpretations” for at least some of the primitive and defined symbols of the calculus, and in that way — supposedly — establishes partial interpretations for the logical calculus by linking it to the observational language, which is assumed to have a direct interpretation as a description of the “real” world.

Advocates of the “non-statement” approach view the rational reconstruction of

the language of science in terms of a syntactic system and a family of interpretations (or models) of that syntax. In opposition to the statement approach's belief that theories are formulated in some (first-order) symbolic language with a set of correspondence rules added somehow, the defenders of the non-statement approach believe in an analysis where the language in which the theory is formulated plays a much smaller role. They hold that foundational problems in the various sciences can in general be better addressed by focussing on the *models* of scientific theories, rather than by reformulating the products of these sciences in some appropriate language, and so they identify a theory with a certain class of mathematical structures.

The non-statement approach has had several branchings since Patrick Suppes has emphasised — against the meta-mathematical musings of the advocates of the received view — the “clarifying” advantages of set-theoretical reconstructions of empirical theories. I shall discuss Suppes's approach in section 4.2. The structuralist programme led by Sneed, Stegmüller, Moulines, and Balzer offers a structural analysis of science, and I shall discuss this programme in section 4.3.² The semantic approach offers an examination of the content of theories via Beth's notion of state-spaces and is supported by Van Fraassen, Suppe, and the (naturalistic) view of science offered by Ronald Giere. These notions are discussed in sections 4.4 and 4.5. I shall unfortunately not, due to limitations of space, discuss the “empiricist semantic” accounts offered by, among others, Wójcicki, and Przelecki. These philosophers both concentrate on offering an empiricist semantics for science — Wójcicki was one of the first who applied the notion of intended application in his analysis of the structure of theories — while also working on the problem of “analyticity”³. They are joined by philosophers such as Tuomela and Rantala⁴, who apply their semantic account of science respectively to problems concerning the nature of theoretical terms and the problems of definability and indefinability in science.

Within the context of my model-theoretic account I also review, in Section 4.6, Nancy Cartwright's views on the nature of “fundamental laws” in science, i.e. the axioms of the deductive set of sentences I refer to as a scientific theory. Cartwright's work is important in my terms since she is currently probably the most influential philosopher of science — writing on the issue of the realism of scientific theories — who does not subscribe to either the statement or the non-statement approaches to science. I do not think that she succeeds either in reconciling or superseding these two approaches though. A model-theoretic account however solves a remarkable number of statement as well as non-statement problems and so supersedes these approaches, reconciling their best features. Cartwright though does pay much attention to general realist issues (think of her pre-occupation with the so-called “lying” laws of physics).

The choice between the statement and non-statement approaches seems trivial as far as theories formulated in first-order languages are concerned. As Theo Kuipers (Kuokkanen, 1994:5) points out, the set of models (that is, structures for which the statements of the theory are true) of theories formulated as a set of statements of some first-order language is exactly the kind of (set of) structures that the defenders of the non-statement approach view as the building blocks of empirical theories. In other words (*ibid.*), possible interrelations between the two approaches exist in so far as an axiomatised theory may be characterised by a class of interpretations which satisfy it,

and an interpretation (or class of interpretations) may be characterised by a set of sentences which it satisfies (and in neither case will the characterisation be unique). Note that in both the statement and non-statement approach the rational reconstruction of a scientific theory is given in terms of an uninterpreted language, which implies, in principle, the possibility of an unlimited number of interpretations of the language. However, in both cases the possible interpretations of the uninterpreted language are limited at least in the following senses. In the statement approach any interpretation must satisfy the axioms of the theory, and in the non-statement approach an interpretation must belong to the described class of structures.

I believe though that clarification of certain core problems in philosophy of science — such as the relations between scientific theories and reality and the notion of scientific truth — is more likely when following the emphasis on models that the non-statement approach offers, while retaining the statement view's analysis of a theory as a (deductively closed) set of sentences. I thus do not go along with either of the two approaches. In the empirical sciences no theoretical entity is ever such a "free creation" of the human mind that its possible links with reality may be discarded in an examination of the various truth relations in which the theory (albeit via its models) stands during the various stages of the scientific process.

I shall set out my own approach in Chapter 2, before continuing to discuss — in Chapter 3 — some of the main points in the statement account of science, and in Chapter 4 I offer explanation and comments on some of the main views in the non-statement school of thought, using model-theoretic realism as a unifying meta-view. In Chapter 5, I shall concentrate on realist issues and offer a model-theoretic interpretation of scientific realism, before concluding on the merits of a model-theoretic realist interpretation of science in the last section of Chapter 5. Since this book is meant as an introductory text in philosophy of science looking at some different applications of formal semantics to realist issues I have tried to minimise the use of formal definitions in logic, although I offer some formalisation of my terminology in Section 2.2.

A brief note on the examples I shall introduce throughout the book. I shall use many well-known examples (such as Newtonian mechanics) to illustrate certain points regarding model-theoretic realism. I choose to do so, since in a comparative sense, different views on the same example seem to be more useful in terms of clarifying points than otherwise. Also I shall refer sometimes (in Chapters 1 and 2) to examples from the philosophy of economics to depict certain aspects of models more clearly. Furthermore I use some very simple examples to illustrate my use of non-monotonic logic (in terms of a minimal model semantics) in model-theoretic realist analyses of the process of science (Chapter 2). For now, though, let us start off by first examining the meaning and use of the notion of "model" in philosophy of science.

On completion of an endeavour such as this, there are always numerous people to thank. I want to thank Johannes Heidema for his comments after proofreading various parts of this text at various times. On a more personal note I thank my son, Franz, for showering me with uncritical love whenever I needed it, and my close family and friends for the various ways in which they helped and supported me towards the completion of this project.

NOTES: INTRODUCTION

¹ Hilary Putnam's term.

² Closely related to the structuralist approach is the approach of Ludwig (1990), which I shall not analyse here, but which is worth mentioning, since it is clearly important, although it does not receive much attention in the English literature on philosophy of science.

³ See Przelecki and Wójcicki (1969).

⁴ Pearce and Rantala (1983) claim that they offer a view in which theories are "abstract systems" free of any explicit logical interpretation. This is very interesting, especially since it seems to allow for problems concerning theories too complex to reconstruct in elementary terms, and also since it makes it possible to allow the choice of logic to be an extra-logical (maybe philosophical?) issue.

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