Emma Ruttkamp. "A model-theoretic interpretation of science", *South African Journal of Philosophy,* Feb 1997, Vol. 16, Issue 1

Abstract

I am arguing that it is only by concentrating on the role of models in theory construction, interpretation and change, that one can study the progress of science sensibly. I define the level at which these models operate as a level above the purely empirical (consisting of various systems in reality) but also indeed below that of the fundamental formal theories (expressed linguistically). The essentially multi-interpretability of the theory at the general, abstract linguistic level, implies that it can potentially make claims about systems in reality, other than the particular one which originally induced it. Any so-called correspondence relation between (systems in) reality and the entities and relations in some scientific theory, thus consists of two jumps or interpretations: from the theory (linguistic level) to some model of it (constructural level); and from there to some system in reality. Clearly then the level of fundamental theories cannot be ignored la Nancy Cartwright - in studying the relations between a theory and reality, because the particular features of the theory (the various systems in reality onto which the theory can be mapped) cannot be studied without the underlying knowledge that these systems have one common feature, namely that each of them is the range (or other pole) of a mapping of a context-specific model of the theory - which in itself, is a mapping, or more specifically, an interpretation of the theory. I am also claiming that the nature of these levels and the relations between them necessitate an epistemological rather than an ontological notion of truth criteria, and a referential rather than a representational link between science and reality.

1. Introduction

One of the most powerful arguments against scientific realism is the so-called argument from scientific revolutions. The argument centres around the seeming contradiction implied by the following question: How is it possible, if scientific realism is true, that the history of science abounds with examples of theories that have had great predictive successes, but that were supposedly 'unmasked' eventually by later science as being 'undeniably and totally false'? I want to offer a possible answer to this question by formulating the outlines of a more 'sophisticated' scientific realism which I will refer to as model-theoretic realism. I shall do this by analysing the relation of so-called 'correspondence between a scientific theory and reality', for which an exposition of the logical development of scientific theories is a prerequisite.

Worrall (1994) offers three possible ways in which scientific realists can approach this argument. He and I choose the same option as the most plausible one, although our approaches and even our interpretations of its possibilities differ. The option we pick is '...to try to show that there is a "level" (below that of the fundamental theories but above the purely empirical) at which there has been continuity or quasi-continuity despite "scientific revolutions"' (Worrall 1994: xxv).

I interpret the purely empirical level as consisting of various systems in reality and our interactions with them, while I view the level of 'the fundamental theories' as a linguistic level - of (linguistic) systems - at which a theory is finally formulated and expressed. Of course one may ask how it is possible to formulate a theory other than linguistically. But what I really mean to emphasize by stressing that the theory is linguistically expressed, is the inescapable abstract, general nature of all linguistic expressions. The reason why this emphasis is necessary, will become clearer when I define the level I claim to exist between the lower level of systems in reality and the higher one of theories formulated in linguistic systems.

I think of this middle level which I want to introduce, as a mainly conceptual level but, for various reasons which will become clearer later, I shall refer to it as the constructural level. Again, one may ask how - and even if - it is possible to distinguish between conceptual and linguistic levels without giving a clear and valid answer to the question of whether it is possible to think without language. And, again, my answer is simply that I am not making rigid distinctions here. What I am doing, in fact, is to explain the development of scientific research - which culminates in the formulation of scientific theories -logically, simply by emphasizing one-by-one the real, conceptual and linguistic aspects of this developmental process. And, moreover, I am not only claiming that there is interplay between these aspects; I require that there must be interplay between them.

In order to explain these stages, the interplay between them, and their role in formulating the outlines of a more sophisticated version of scientific realism as clearly and intelligibly as possible, neat and explicit definitions of key terms are needed. To do this, I will invoke the help of certain definitions and theorems of mathematical Model Theory2, as exemplifications of my key notions. It must be understood that this does not imply that I am claiming that every theory must be formulated in a formal language, or that a mathematical structure has to be defined for every interpretation of a theory. I am rather, as already stated, implementing these mathematical notions because of mathematics' special characteristics of exactness and distinctness. And, since notions such as 'model'interpretation', 'relation', 'true' and so on, have been interpreted and applied in so many different ways in philosophy of science over the years, and as they play key roles in my paper, using the definitions of these notions as they are expounded in Model Theory, seems to be a good idea. This mainly comes down to the fact that I see the construction of interpretations and models in Model Theory as analogous to what happens when a scientific theory is interpreted. But, this implies that the logically distinguishable aspects of the development of a scientific theory have to be such that these sorts of notions can be applied to them. And this makes a study of the origins of a theory - or the movement from an aspect of reality to an abstract linguistic formulation of a scientific theory - an integral part of a study of the theory's interpretations.

So, in what follows, I will expound this movement in terms of the three levels present in both its construction and its interpretation (application). Very briefly, I see a scientist's research as starting from a certain system distinguished in reality, moving to a constructural level where the scientist will formulate the particular intended model for her research, and ending with an abstract general formulation of the theory, as a linguistic description of this intended model. The important point is that this theory may, at this third level, be seen as essentially multi-interpretable in the following very simple and evident sense: This theory will be expressed in general terms (as will be explained in Section 2), that is, it will make claims not only about the particular system (in reality) which was its original inducement. And thus, as is the case with any general statement, its particular instances are only potentially implied, not yet filled in. This is what being general means.

Now I want to retrace this movement by moving the other way, that is, by starting from the formulated theory and trying to analyse its relation -if any - with some (systems in) reality. What happens if scientists become interested in a specific theory?3 They must interpret the general theory in such a way that it becomes meaningful to their (intended) research. And, I claim, they do this by creating or constructing in their turn, certain conceptual context-specific models of the linguistically formulated theory. But that brings them only to the middle level of my exposition. The last move that is needed - that is, from this constructural level to systems in reality - is a second interpretation (say a mapping or linkage or conformation) in the sense that the concepts in the context-specific models at the constructural level, are given meanings in terms of entities and relations perceived in systems in reality.

In short, I shall thus describe a scientific theory as a set of uninterpreted' statements, with the potential of being interpreted in any number of ways. This holds the promise of a variety of particular interpretations of that one - unifying - theory, and, of a variety of particular linkages of those context-specific interpretations (models) to aspects of reality. All of this together constitutes the movement from some system in reality to the formulation of the theory and back to some system(s) in reality again.

Before I go on to explain my proposal for model-theoretic realism in more detail, I want to point out some of its important consequences -the over-all objective still being to lead to a more pliant and sophisticated version of scientific realism.

(1) It has the potential to redefine, and so to refine, the notion of correspondence itself, as being much more than a sort of glorified truth criterion for scientific knowledge.

(2) Applied to truth criteria in general, it has very obvious implications for any version of truth as an absolute notion. And more importantly, it helps to clarify the typically realist claims of 'approximate' or 'essential' truth, by invoking an epistemological theory of truth. Also, the concept of reference will clearly be influenced by this interpretation of truth.

(3) It can make sense of scientific realism and scientific revolutions at the same time.

(4) Finally, it helps to give a clearer over-all description of science as being a process in which our knowledge of reality is neither incommensurable, disconnected 'pockets' of knowledge claims, nor simply boringly accumulative, but as rather being somewhere in between.

2. The composition of a scientific theory

I will start by explaining in more detail the three (main) overlapping and mutually dependent - stages of the logical development of a (scientific) theory, that I have already mentioned in the previous section. I will use a rational reconstruction of the development of Newton's theory of sola[systems (in particular) to illustrate my explanations concretely.

Newton wanted to do research about the movement of the planets in our solar system. But, since he couldn't study all the complexities of this system as it manifests itself in the manifold of reality, he identified the details necessary for his research goal, by abstracting from tiffs system in reality only those specific features in which he was interested. He would have discarded, for instance, the fact that the sun's rays are hot, that Mars seems to be reddish in colour, and so on, Thus, even the identification of certain data as purely empirical is already a particular interested-directed choice. So, in this way, because his abstractions were so closely guided by his intentions, he would never really have been dealing with the bare data that he had extracted from the system in reality. He would, rather, have been dealing with a conceptualized context-specific model of our solar system, thus extending his abstractions by combining them with his intentions. Here he was thus dealing with data chosen for certain context-specific reasons implying that the nature of this data can never be as objectively pure as some philosophers would perhaps like. I will call this conceptualized model Newton's intended model for obvious reasons. Clearly the models constructed at this level are neither directly derivable from reality - although they do arize from convictions about reality - but nor is their nature of the same degree of generality as that of the linguisticanalytical statements of the theory.

A final comment on the nature of the intended model, and indirectly then, on the nature of this constructural level. Evidently, the construction of the intended model is closely guided by personal motivations and research intentions, and these factors, in their turn, are guided by so-called thematic preferences (Holton, 1995). Among these preferences, those fundamental presuppositions, held consciously or unconsciously, which show up in the motivation of scientists actual day..to-day work as well as in the end product (Holton 1995:456) are to be found. Einstein spoke in this sense of free coventions (Ibid: 464). Examples of the preferences or conventions which particularly guided his theory construction are ... the primacy of formal (rather than materialistic or mechanistic) explanation, unity or unification, cosmological scale in the applicability of laws, logical parsimony and necessity, symmetry, as long as possible, simplicity, causality (in essentially the Newtonian sense), completeness and exhaustiveness, continuum, and of course constancy and invariance. These themata, to which Einstein was obstinately devoted, explain why he would continue his work in a given direction even when the tests against experience were difficult and unavailable (as in General Theory of Relativity), or, conversely, why he refused to accept theories well supported by phenomena, but, as in the case of Bohr's quantum mechanics, based on presuppositions opposite to his own, namely discontinuity, inherent probabilism, and the abandonment of completeness in the description of phenomena' (Ibid: 457).

Back to Newton. Based on his research (i.e. his laws) and its implications, he would have attempted - possibly many times to articulate the content of his model and the results of his research concretely in some linguistic form. Einstein again: 'Conventional words or signs have to be sought for laboriously only in a secondary stage ...' (Einstein 1954: 25-26, my italics.) Thus, a constant interplay between the constructural and linguistic levels would have finally resulted in a linguistic formulation of his findings - be it in a formal language, a natural language or a combination of the two. This I identify as the theory (of solar systems in this case). This theory would be essentially multiinterpretable, in the following sense: Because of its formulation in language, and because of its development from a level where certain abstractions have already been in use, it would have an inherently general nature. And, as I have briefly stated in the Introduction, generality always implies multi-interpretability' as the promise of a variety of ways to interpret any general statement. I therefore think of the move from the system in the real world to the formal-linguistic system in terms of the degrees of comparison of 'general'.

3. Interpreting a scientific theory

Clearly, if I now want to retrace the stages in this development, I have to make two 'jumps' to get 'back to' (some system in) reality. The first jump is the easiest one, and can be explained more or less unproblematically, because such an explanation is analogous to explaining a mathematical interpretation of a formal language statement. The second jump, though of roughly the same type as the previous one, is much more problematic, mainly because of three reasons. I shall expound on them in subsection 3.2 below.

3.1 The move from the theory to its interpretations or models

As promised in Section 1, I will employ certain model-theoretic notions to illustrate as intelligibly as possible, some of the possible implications of the particular model of the development and interpretation of a scientific theory I am proposing. I will concentrate on the treatment in mathematical logic of the relationship between, on one hand, expressions; which for the purposes of this paper, I like to think of as the formal-linguistic form of a theory and, on the other, mathematical structures realizing these expressions - which I am thinking of as models determined by the various contexts in which one theory can be applied by the various scientists interpreting it, and which assign reference to the signs and sentences of the theory.

I shall begin by informally explaining the notions of interpretation and model as they are used in Model Theory. Let's say that theory T is the (deductively closed) set of sentences which can be deduced from a consistent set of axioms, E, in formal language L. Now, in this language, L, there will be - amongst other things-an infinite, countable set of variables and a nonempty set of predicate letters. Then, it is possible for a mathematician (or scientist' for my purposes) to give meaning to the symbols in language L used to formulate the sentences in theory T, by constructing a certain mathematical structure suitable to be described by the language L.

This structure, U, will consist of a set of elements (called the domain of the structure) on which a set of relations will be defined. Now, the moment that every n-ary predicate symbol in language L, is associated with an n-ary relation in structure U, we can say that this mathematical structure is an interpretation of the language L, and thus by implication of any sentence in L. What is important to realize, is that of course, for every other definition of the domain of the mathematical structure and of the relations defined on it, one is confronted with another interpretation of the language.

Coming then to the notion of a 'model' of a sentence in the language, I want to emphasize the special meaning - an epistemological (rather than an ontological) meaning - which is ascribed to the notion of truth in Model Theory.

If every free occurrence of variables in a formula in language L, refers to an element in the domain of an interpretation of L by means of a specific valuation (which is a simple function ascribing one value from the domain to each variable in L) it becomes possible to define the notion of a model. A model of this formula will be an interpretation under which that formula is true by the specific valuation defined for its (the formula's) variables. For example, consider the formula Pxy. If P is interpreted as the relation < and if x and y are given the values of 3 and 5 respectively, then we say that Pxy is true under that interpretation and we say that formula Pxy in language L is satisfied by the valuation in the domain of interpretation U, ascribing the given values to variables x and y. (Because 3 is indeed smaller than 5.)

Now, a sentence is a formula with no free occurrence of variables. But this definition (of the truth of a formula) implies that a sentence will either be true under a interpretation by all possible valuations or false under all valuations. Hence for sentences we may speak of truth under an interpretation without mentioning valuations. And, a set of sentences is true under an interpretation if every sentence is true under that interpretation. Thus a model of a theory (being a set of sentences in some formal language L) will be an interpretation under which that set of sentences is true.

This implies of course, that it is the set of elements in the domain of interpretation U and the definition of the relations on that domain which determines the 'truth' of a sentence - or a set of sentences - in language L. In other words, if a sentence is true under interpretation U (1) it is not necessarily true under interpretation U2. The notion of 'truth' in this sense is thus a simple epistemological one in the sense of being a notion of satisfaction of certain truth criteria.

So, in the sense of studying the interpretations of scientific theories and not necessarily of the sentences in some formal language these mathematical discussions analogously suggest the following. Firstly, note that by 'interpretation' I mean the assignment of reference and not merely 'elaboration' or explanation'. A scientist, interested in a theory (e.g. Newton's theory of solar systems) will construct a specific interpretation of it, the structure of which will be determined by the particular context in which this scientist is working. This context, in its turn, will be determined by the scientist's research, intentions and objectives and may thus, in principle, differ from the context(s) in which any other scientist(s), interested in the same theory, are working. (See Footnote 3 again.) Let's from now on call Newton the 'original scientist' and any other scientists considering his theory interpreter-scientists'.

For the sake of clarity, I want to emphasize that these interpretations or models are constructed within specific contexts. The model is a specific interpretation of the theory in which all its (the theory's) sentences are true. But, I see the same role for thematic preferences, personal motivations and research goals here as in the construction of the intended model. Thus, one must distinguish between model and context, in the sense that thematic preferences shape the contexts in which scientists work, and these contexts, in their turn, shape the construction of specific interpretations or models of theories.

If, in analogy to the mathematical notions set out above, I thus take the set of axioms, Z, to be Newton's theory of solar systems expressed formally, I can with the following example illustrate the use of different models to interpret one theory. Until 1820, a group of 'interpreter-scientists' of Newton's law of gravitation and his three laws of motion had worked in a model of these laws representing our solar system as consisting of only seven planets. Then, in 1820, calculations carried out within this model, started to give wrong predictions. It then became apparent that the motion of Uranus 'did not conform to Newton's grand scheme' (Schwinger 1986:195). The possibility that the motion of Uranus could be affected by another planet seemed a good solution to the problem. So, scientists thought of postulating the existence of an eighth planet, and thus the construction of a new model, now with eight planets. In 1845 John Adams calculated the position of the 'new' planet in our solar system, and shortly afterwards Urbain Leverrier's calculations confirnmed his findings. Finally, in September 1846, the predicted planet, Neptune, was discovered.

The only way, in this respect, in which a scientist can preclude her theory from being interpreted in ways contrary to her intentions and beliefs, would be by logically strengthening the theory's set of axiomatic assumptions (z). But, obviously this is a very difficult task, especially in the first stages of the theory's formulation. And, moreover, trying to define these assumptions too finely could, in principle, cancel the possibility of refining the theory in a positive way when shortcomings or even errors in the formulation of the theory become apparent via different models of it.

3.2 The move from the models of the theory to reality

In moving now to the so-called 'second jump', that is, from the constructural level to systems in reality, I want to emphasize the following:

(a) This jump - from the constructural level to some system in reality -is often mistaken for a 'jump' from the scientific theory itself to - an aspect of - reality. Thus, in the process, the constructural, middle level is entirely ignored.

(b) This second jump is the relation which traditionally addresses the problematic notion of so-called 'correspondence' between concepts named by the terms in a theory and entities in reality.

(c) The first jump is a jump to some context-specific model or interpretation which the person interpreting the theory constructs (creates), but the second jump is to an aspect of reality already existing (in a certain sense) which naturally complicates the nature of the jump.4

Here, I think, a comment on the use of the term constructural is appropriate. It is meant to refer to the two main features of this level, namely that constructions are being created (the contextspecific models) and that their structural, composition which has a direct relation to the truth criteria of the context-specific model - is determined context-specifically?

Then, more specifically, concerning the nature of the relation between a context-specific model and an aspect of reality, the following: This relation too, is analogous to that of a mathematical interpretation constructed for interpreting the sentences in some formal language. The concepts in the model(s) are given 'real world' meanings via this relation. And, just as the different models that can potentially exist at this constructural level may differ from each other, so the mappings of their terms onto entities in systems in reality may differ and so there may even be different systems to which they are mapped in the real world.

The version of this relation as being between the theory and reality renders questions about scientific revolutions resulting in so-called 'paradigm' - or theory - shifts unanswerable within a strict (scientific) realist context. The reason for this is simply that according to a realist view, the terms of a predictively successful theory will refer to some entity(ies) in the real world. But, if this theory is later claimed to have been radically false, the question about the adequacy of this relation, which supposedly mapped the terms of the theory onto entities in reality, arises.

As I have pointed out briefly above, the problem here is that the co-ordinating role of this constructural level, operating between the theory and (systems in) reality is ignored. If this level is taken into account, however, the problem becomes rather more trivial. More about this in the next section.

4. Conclusion

4.1 General

The claim carrying the most weight in this paper, is that the most important feature of a theory. is its potential to be interpreted in a multiplicity of context-specific models. This multiplicity doesn't provide evidence for anti-realist allegations of contradictions - in the sense of the argument from scientific revolutions - but, on the contrary, has the promise of coming closer to a better - I hope - more encompassing description of nature.

My claim, therefore, is that theories should be seen as sets of sentences which, via their potential models, are given empirical meaning only inasmuch as they are applied (semantically) to certain specific, context-particular, limited areas of empirical reality, via context-specific models of them. Explanations and predictions provided by a theory do not make claims about reality in some unique way, fixed beforehand once and for all in some mirroring relation of language to reality, but are indeed very much a function of the particular model in use in some particular context at the time. I therefore see a scientific theory as mapping limited, context-particular sections of any system in the real world by introducing simplifying (via abstraction) assumptions which are adjusted - or even removed - in the light of its models' respective predictive successes.

4.2 Model-theoretic realism

(i) The tricky notion of correspondence

I have already commented on the nature of the relation of correspondence' between the terms of a theory and reality, and I have, most importantly, pointed out that this relation is actually between the constructural level of context-specific models of the theory and systems in reality. The reason why this is so important is that it is the variability or variety of models of the theory possible(6) at the constructural level, which explains so many of the problems philosophers have with scientific realism. And, of course if one 'jumps' straight from the theory to reality this mediating or co-ordinating middle level is completely bypassed.

Why is this middle level a level of mediation? It is the first step in a particular application of the general theory, and it promises a further specific characterisation because some of its context-specific models may refer to even more specific entities in some system of reality. Thus, it mediates between the general and the particular, and it offers the possibility of inverting the initial action of abstraction from a system in reality which led to the theory at the formal-linguistic level in the first place.

(ii) Truth criteria

It is precisely this feature of the logical development of scientific theories which enables less naturalistically inclined philosophies of science to still hold on to some version of realism in the following referential [Hans Radder's (1993) term] way. In a modeltheoretic version of scientific realism there are two sets of truth criteria which need to be taken into account. The first set is found at the constructural level and is model-specific in the sense that the structure of the models determines its nature. Thus, the theory can be said to be true in each independent model thereof, under specific interpretations. Reference is in terms of entities and relations in the context-specific model. But that is all. It is with the second set of truth criteria, which can be specified relative to some system in reality, that truth in the sense of reference to entities and relations in systems in reality can be appraised for the first time because only then will it be the particular system in reality which will determine when and if the relations in the model mapping that particular real system, are true of it or not. And so these system-specific truth criteria are simply so far removed from the general abstract linguistic theory that their nature is far too particular for them to have the power to determine the 'truth' of the general theory in some absolute sense, independent of any specific model and its particular linkage to some system in reality. Thus, the answer to the question of the truth of a theory can never be in the same general terms as the theory. It can only be in terms of reference and is never representational (in the sense of perfect mirroring of reality).

Having said this about truth, and having taken into account that the relation of reference is built into the structure of any truth criterion (regardless of whether the structure which is referred to, leads to the satisfaction of this truth criterion or not), it should be evident that the referential relation too, has to be understood in model-theoretic terms. Reference in a model-theoretic context is something far removed from absolute universal relations of reference between language terms in a theory and entities and relations in reality. The linguistic terms in the theory refer to entities and relations in the context-specific model, and these stand in some referential relation to entities and relations in some system of reality. Therefore, if one takes the complexity of the constructural level and its promise of various possible links to systems in reality into account, it becomes clear that all that can be said about reference to reality is that some model-specific terms may refer to system-specific entities and relations in reality, but the nature of these entities and relations themselves cannot be prescribed or explained (by the theory) in any absolute universal way. Statements of this kind can only be made relevant to some context-specific model and the specific system in reality to which it is linked.

(iii) The argument from scientific revolutions

The formal-linguistic level, however, cannot for these reasons be ignored [as Nancy Cartwright (1983) seems to be advocating], because it is needed to organize and classify knowledge in the efficient manner which makes precise calculations possible. Explanations and predictions are thus indeed features of the theory, but only potentially, because of the theory's abstract (and general) nature. The content of scientific knowledge can only be expressed by interpreting these abstract terms in some contextspecific model at the constructural level. Neither of these levels' roles in the development of scientific knowledge can thus be appreciated if one is studied without the other.

Moreover, the sets of thematic preferences guiding the construction of these context-specific models, aren't rigid, dogmatic closed-off entities allowing no communication between, or overlap of, these sets of preferences. Much rather, communication is possible and it may lead either to agreement or disagreement. Einstein and Niels Bohr agreed far more than they differed, and moreover, they knew why they differed so that the difference between their respective sets of thematic preferences did not imply any form of incommensurability. The process of science has an evolutionary, cumulative character, rather than a discontinuous authoritarian one.

In this respect then, the reason why model-theoretic realism offers a possible counter-argument to the argument from scientific revolutions (or why it at least softens the implications for scientific realism), is that it describes a theory (or paradigm) shift not in terms of incommensurability (gila Kuhn)7 but rather in terms of continuity at the constructural level. It is simply the case that, because of the epistemological notion of truth generated by this level, it offers the possibility that a so-called discarded theory may still have models in which that theory can be true. It is an interpretation of Newton's theory that is still used to send people to the moon - although his theory has been (supposedly) discarded in favour of that of Einstein's.

(iv) The process of science

The metaphor of a clock(8) adequately describes my view of the process of science. Take the hour-hand to represent scientific theories at the general linguistic level, the minute-hand to represent context-specific models of these theories at the constructural level, and, finally, the second-hand to represent empirical data at the level of reality. I claim then that the progress of science - in terms of the three levels - is similar to the speed of the hands of the clock. Theories change very slowly, models more quickly and empirical data the quickest. A theory change occurs only when the possibility of changing its models has been exhausted. And, still within this metaphor, it follows that I regard the accumulation of scientific knowledge as being the result of the continuity implied by the interplay between these levels as illustrated by the relationship between seconds, minutes and hours. In this model-theoretic sense, I think it is clear then that any view of the process of science in terms of incommensurable discontinuous theory shifts is simply too extreme and in a sense, much too simple.

Acknowledgement

My thanks to the HSRC for the role they played in my attending a conference on Images and reality in Hungary (June 1996) where I read a paper on model-theoretic realism.

Notes

1. *The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The physical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be "voluntarily" reproduced and combined .... taken from a psychological viewpoint, this eombinatory play seems to be the essential feature in productive thought - before there is any connection with logical construction in words or other kinds of signs which can be communicated to others' (Einstein 1954: 25, 26.)*

2. *For formal background see Tarski, A. (1956) and Bridge, J. (1977).*

3. Note that the original formulator of the theory may be among these interested scientists - for instance, she may be simply looking at some other aspect of reality. The particularity of each model does not imply subjectivity, but rather intersubjectivity in the sense of communicability.

4. Let me briefly make one comment on the sense in which I claim reality to be 'already existing'. I acknowledge that the notion of reality' is influenced by the interplay between accepted scientific theories and experiences of reality and in this sense I allow the notion of reality as being changeable (in the sense of having certain 'constructed'features), although this does not imply that no notion of reality already out there on to which the constructive-contextual terms in the context-specific models are mapped, is possible. This in its turn implies that the mapping itself is never an absolute perfect mapping in the sense of the theory mirroring unchanging reality, because firstly my notion of reality is not that of an unchangeable blueprint of the universe, and secondly, the mapping is not between the theory and reality but rather between context-specific models at the constructural level and aspects of reality. And, moreover, the potential variety of mappings possible to be made from the theory's multiplicity of context-specific models further renders the notion of one perfect mapping impossible.

5. Another significant implication of model-theoretic realism is that it offers a way in which it is possible to study within a realist framework, the role of the productive features of scientific development, emphasized already in the thirties by philosophers like Gaston Bachelard (1984). Thus it becomes possible to analyse the apparent dilemma in studying a reality which seems to be both independent of the existence of human beings and also very much dependent on the actions of the scientists studying it (Radder 1993: 332). The supple character of the constructural level offers the chance to analyse more clearly this co-enriching relationship between science and reality, because its nature offers the possibility of studying the place of recurrent socio-historical factors in theoretical change from within a realist framework and thus to acknowledge possible interplay between systems in reality and scientific (context-specific) models of theories.

6. Possible worlds' is meant not in Lewis's sense of fantastical worlds existing, but simply in the sense of every 'possible world' potentially mapping some aspect of *reality at the constructural level. Margolis: 'There are no "possible worlds", other than the actual world, that exist de re' (Margolis 1995:105).*

7. *Lakatos, I. and Musgrave, A. (1970).*

8. *I have J. Heidema from the Department of Mathematics, Applied Mathematics and Astronomy at the University of South Africa, to thank for this metaphor.*

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